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RESERVOIR NUMBER ONE (.. (U) CORPS OF ENGINEERS WALTHAM
MA NEW ENGLAND DIV APR 79

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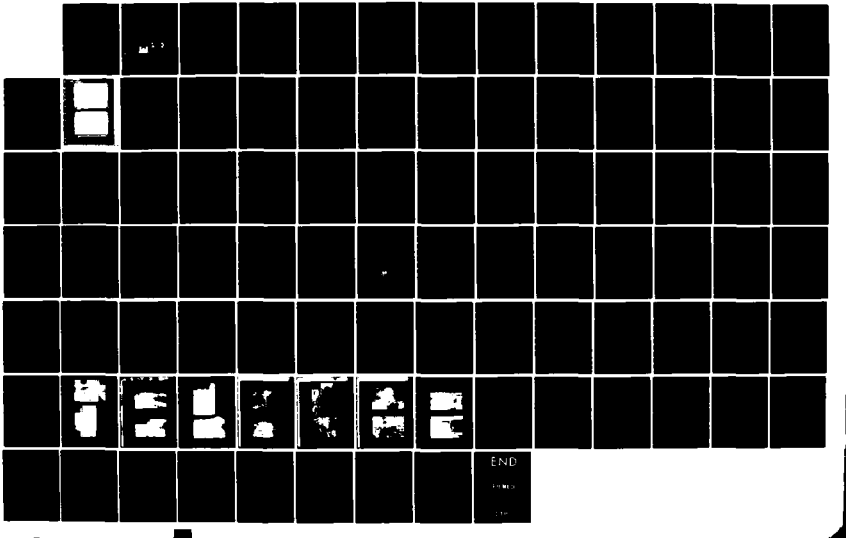

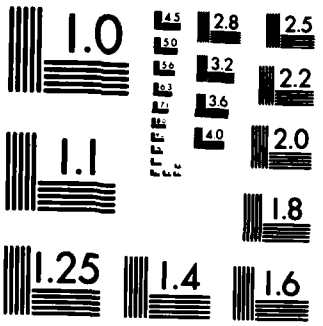

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Cover program reads: Phase I Inspection Report, National Dam Inspection Program; however, the official title of the program is: National Program for Inspection of Non-Federal Dams; use cover date for date of report.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

DAMS, INSPECTION, DAM SAFETY,
Merrimack River Basin
Framingham, Massachusetts
Sudbury River

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Total length of the dam ia about 800 ft. with a height of about 22 ft. The Although there were some minor deficiencies noted the dam is cosidered to be in good condition. It is intermediate in size with a hazard potential of high.

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DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02154

REPLY TO
ATTENTION OF:

NEDED

AUG 02 1979

Honorable Edward J. King
Governor of the Commonwealth of
Massachusetts
State House
Boston, Massachusetts 02133

Dear Governor King:

I am forwarding to you a copy of the Reservoir Number One Dam Phase I Inspection Report, which was prepared under the National Program for Inspection of Non-Federal Dams. This report is presented for your use and is based upon a visual inspection, a review of the past performance and a brief hydrological study of the dam. A brief assessment is included at the beginning of the report. I have approved the report and support the findings and recommendations described in Section 7 and ask that you keep me informed of the actions taken to implement them. This follow-up action is a vitally important part of this program.

A copy of this report has been forwarded to the Department of Environmental Quality Engineering, the cooperating agency for the Commonwealth of Massachusetts. In addition, a copy of the report has also been furnished the owner, Metropolitan District Commission of Massachusetts (MDC), 20 Somerset Street, Boston, Massachusetts 02108.

Copies of this report will be made available to the public, upon request, by this office under the Freedom of Information Act. In the case of this report the release date will be thirty days from the date of this letter.

I wish to take this opportunity to thank you and the Department of Environmental Quality Engineering for your cooperation in carrying out this program.

Sincerely yours,

Mark Scheider

MAX B. SCHEIDER
Colonel, Corps of Engineers
Division Engineer

Incl
As stated

MERRIMACK RIVER BASIN
FRAMINGHAM, MASSACHUSETTS

RESERVOIR NUMBER ONE

MA 00337

PHASE I INSPECTION REPORT

NATIONAL DAM INSPECTION PROGRAM

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS. 02154

APRIL 1979

PHASE I INVESTIGATION REPORT
NATIONAL DAM INSPECTION PROGRAM

Identification No.:	MA 00337
Name of Dam:	Reservoir Number One (Winter Street)
Town:	Framingham
County:	Middlesex
State:	Massachusetts
Stream:	Sudbury River
Date of Site Visit:	29 March 1979

BRIEF ASSESSMENT

Reservoir Number One Dam consists of two earth embankments separated by a 168 ft. long stone masonry spillway and a gate house structure containing the regulating outlet controls. The total length of the dam is approximately 800 ft., and its maximum height is about 22 ft. The dam was completed in 1878. It is owned and operated by the Metropolitan District Commission of Massachusetts (MDC) to provide an emergency water supply and to regulate flow in the Sudbury River.

Due to the extent of downstream development that would be affected in the event the dam were to fail, Reservoir Number One Dam is confirmed as having a "high" hazard potential in accordance with Corps of Engineers guidelines.

The dam is in good condition, based on a visual examination of the structure, although the spillway weir was partially obscured by flowing water. Some minor deficiencies were noted; however, there was no evidence of settlement, lateral movement or other signs of structural failure, or other conditions which would warrant urgent remedial action.

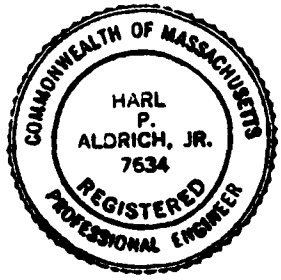
Based on the "intermediate" size and "high" hazard potential classifications in accordance with Corps of Engineers guidelines, the test flood for this dam is the Probable Maximum Flood (PMF). Hydraulic analyses indicate that the test flood outflow of 18,800 cfs (inflow 20,000 cfs or 270 csm) would overtop the dam by about 4 ft. With the water level at the top of dam, the ungated spillway capacity is approximately 4,600 cfs, which is 24 percent of the test flood outflow. This is because downstream channel conditions control the amount of discharge from the dam. If the downstream channel capacity was adequate, the spillway capacity would be about 92 percent of the test flood outflow.

The MDC, owner of the dam, should assign or engage a registered professional engineer to assess the condition

of 1) the spillway weir and apron after observing them during a time of low or no flow over the spillway and 2) the outlet chambers, as outlined in Section 7.2. Any necessary modifications resulting from the investigations, and remedial measures, including repairing the localized erosion of the embankments, repointing granite masonry as required, and repairing the gate house, right wall of the discharge channel and wooden porch downstream of the gate house, as outlined in Section 7.3, should be implemented by the Owner within two years after receipt of this report. The Owner should also prepare a formal operations and maintenance manual for the dam and establish an emergency preparedness plan.

HALEY & ALDRICH, INC.
by:

Harl Aldrich
President



This Phase I Inspection Report on Reservoir Number One has been reviewed by the undersigned Review Board members. In our opinion, the reported findings, conclusions, and recommendations are consistent with the Recommended Guidelines for Safety Inspection of Dams, and with good engineering judgment and practice, and is hereby submitted for approval.

Joseph A. McElroy

JOSEPH A. MCELROY, MEMBER
Foundation & Materials Branch
Engineering Division

Carney M. Terzian

CARNEY M. TERZIAN, MEMBER
Design Branch
Engineering Division

Joseph W. Finegan, Jr.

JOSEPH W. FINEGAN, JR., CHAIRMAN
Chief, Reservoir Control Center
Water Control Branch
Engineering Division

APPROVAL RECOMMENDED:

Joe B. Fryar

JOE B. FRYAR
Chief, Engineering Division

PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the office of Chief of Engineers, Washington, DC 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation, and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I Investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I Investigations are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the test flood is based on the estimated "probable maximum flood" for the region (greatest reasonably possible storm run-off), or a fraction thereof. Because of the magnitude and rarity of such a storm event, a finding that a spillway will not pass the test flood should not be interpreted as necessarily posing a highly inadequate condition. The test flood provides a measure of relative spillway capacity and serves as an aid in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential. Consideration of downstream flooding other than in the event of a dam failure is beyond the scope of this investigation.

The Phase I Investigation does not include an assessment of the need for fences, gates, no-trespassing signs, repairs to existing fences and railings and other items which may be needed to minimize trespass and provide greater security for the facility and safety to the public. An evaluation of the project for compliance with OSHA rules and regulations is also excluded.

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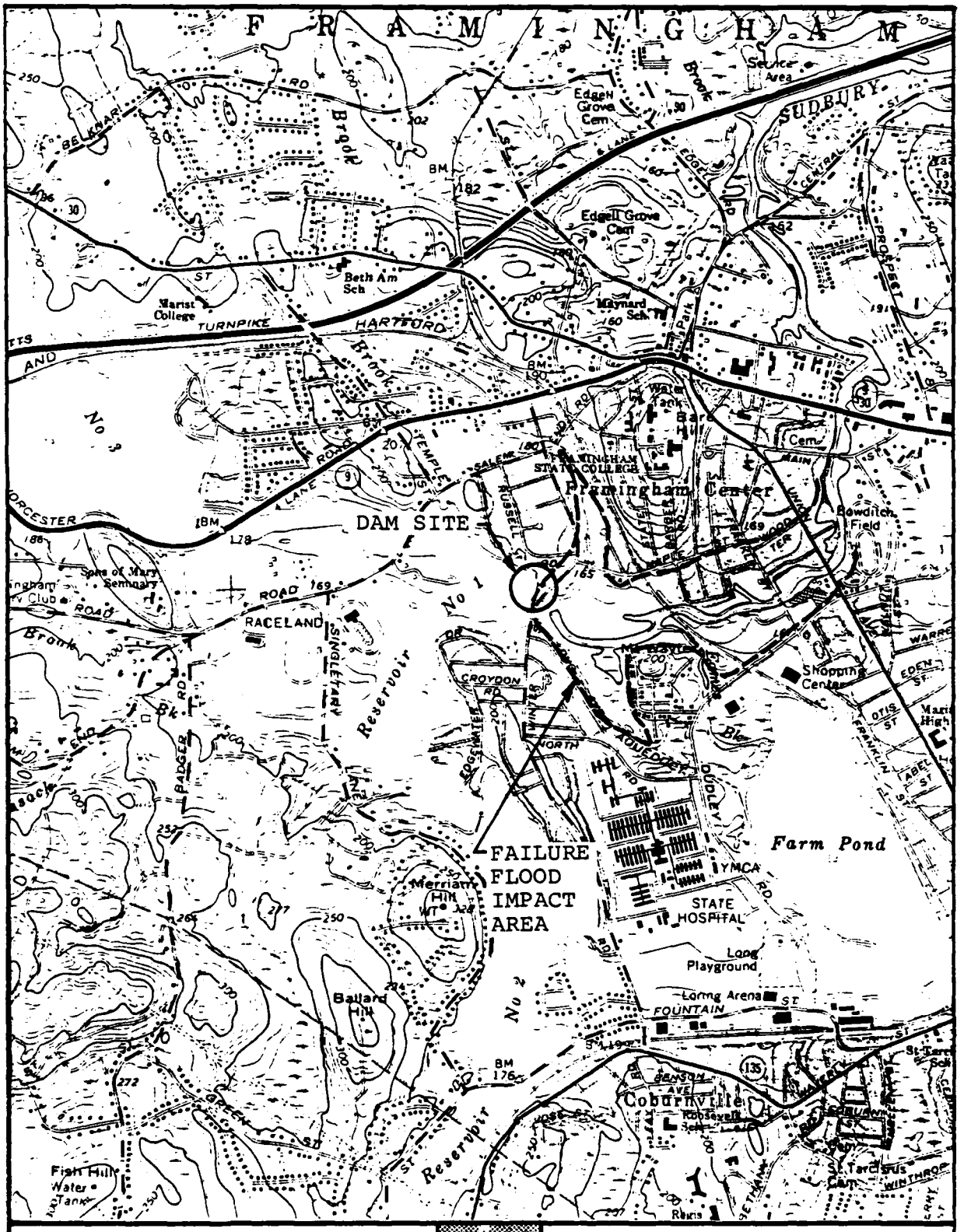
SECTION 4 - OPERATIONAL PROCEDURES

4.1 Procedures

There are no formal operational procedures other than



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DAM: RESERVOIR NUMBER ONE

IDENTIFICATION NO. MA 00337

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LOCATION MAP
USGS QUADRANGLE

FRAMINGHAM, MA

APPROX. SCALE: 1"= 2000'

PHASE I INVESTIGATION REPORT
NATIONAL DAM INSPECTION PROGRAM
RESERVOIR NUMBER ONE DAM
MA 00337

SECTION 1 - PROJECT INFORMATION

1.1 General

a. Authority. Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a National Program of Dam Inspection throughout the United States. The New England Division of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the New England Region.

Haley & Aldrich, Inc. has been retained by the New England Division to inspect and report on selected dams in the State of Massachusetts. Authorization and notice to proceed were issued to Haley & Aldrich, Inc. under a letter dated 28 November 1978 from Colonel Max B. Scheider, Corps of Engineers. Contract No. DACW33-79-C-0018 has been assigned by the Corps of Engineers for this work. Camp, Dresser & McKee, Inc. was retained as consultant to Haley & Aldrich, Inc. on the structural, mechanical/electrical and hydraulic/ hydrologic aspects of the Investigation.

b. Purpose of Inspection. The primary purposes of the National Dam Inspection Program are to:

1. Perform technical inspection and evaluation of non-Federal dams to identify conditions which threaten the public safety and thus permit correction in a timely manner by non-Federal interests.

2. Encourage and prepare the states to initiate quickly effective dam safety programs for non-Federal dams.

3. To update, verify and complete the National Inventory of Dams.

1.2 Description of Project

a. Location. The dam is located at the east end of MDC Reservoir Number One (Stearns Reservoir) in Framingham, MA, as shown on the Location Map, page vii, at approximate coordinates N 42° 17.5', W 71° 26.6'. Spillway discharge from the dam is conveyed by the Sudbury River to Concord, where it joins the Assabet River. The combined streams form the Concord River, which flows into the Merrimack River in Lowell.

b. Description of Dam and Appurtenances. Reservoir Number One Dam consists of two earth embankments separated by a stone masonry spillway and a gate house structure. The total length of the dam is approximately 800 ft. The Site Plan Sketch, page C-1, shows the general configuration of the project. More detailed plans, profiles and sections are shown on drawings in Appendix B.

The left and right embankments were measured to be 216 and 347 ft. in length, respectively. The embankments have a maximum height of approximately 22 ft., relative to the spillway discharge channel. The dam is constructed in sand and gravel deposits, as shown in longitudinal section on page B-19. Relative to the downstream toe, the maximum heights of the left and right embankments (looking downstream) are 12.7 and 10.5 ft., respectively. The embankments have a stone masonry core wall and a 20 ft. wide crest, as shown in sections on pages B-21 and B-22. Slopes are 2 horizontal to 1 vertical on both the upstream and downstream sides. The upstream face is protected by stone paving below a level approximately 3 ft. below the top of the embankment.

The 168 ft. long overflow spillway crest is approximately 9.5 ft. lower than the top of dam, as measured at the left spillway wall. The spillway weir and apron are of stone masonry construction, extending to a considerable depth and with sheet piling as shown on the sectional drawings, pages B-21 and B-22. The spillway was designed to operate with up to 1.75 ft. of flashboards, which have not recently been used.

A gate house structure is located to the right of the spillway. A 48-in. cast-iron supply pipe from the higher Reservoirs No. 2 and 3 enters the upstream side of the structure. The arrangement of ten gates and various chambers in the gate house is such that water from Reservoir No. 1 and/or water from the 48-in. pipe can be released to the Sudbury River or diverted into a horseshoe-shaped water supply aqueduct built below the ground surface from the gate house to Farm Pond. A plan and elevation views of the gate house are shown on page

B-20, and sections are shown on pages B-21 and B-22.

c. Size Classification. Reservoir Number One Dam has an estimated maximum storage capacity of 3,075 acre-ft. at the top of the dam. The maximum hydraulic height is about 22 ft. According to guidelines established by the Corps of Engineers, storage of from 1,000 to 50,000 acre-ft. classifies this dam in the "intermediate" size category.

d. Hazard Classification. Based on the Phase I investigations and dam failure analyses in accordance with Corps of Engineers guidelines, Reservoir Number One Dam was found to have "high" hazard potential. If the dam were to fail, a large residential area including a school along the left bank and an industrial-commercial area, including another school, on the right bank of the downstream channel are expected to be seriously flooded. Therefore, the potential for loss of lives and extensive damage to both industrial-commercial and residential properties is extremely high.

e. Ownership. The dam is owned by the Metropolitan District Commission of Massachusetts (MDC), 20 Somerset Street, Boston, MA 02108. The MDC became the owner in 1919 by Chapter 350 of General Acts of 1919. The original owner was the Metropolitan Water and Sewerage Board.

f. Operator. The operation, maintenance and safety of the dam is the responsibility of the Sudbury Section of the MDC, 311 Hollis Street, Framingham, MA. The Superintendent of the Sudbury Section is Mr. Edward Ginsburg (phone: 617/872-4388). Mr. Ginsburg has been associated with the dam since 1970.

g. Purpose of Dam. The dam was constructed to create a water supply reservoir for the Metropolitan Boston area. The current purpose of the dam and reservoir is for an emergency water supply and to regulate flow on the Sudbury River.

h. Design and Construction History. Reservoir Number One Dam was constructed from 1876 to 1878 by the Metropolitan Water and Sewerage Board as one of three major water supply reservoirs on the Sudbury River. The general design considerations and construction features of the three dams and reservoirs and specific information on

Reservoir Number One Dam are included in a Boston Water Works report dated 1882. Pertinent sections and four record drawings from that report are included in Appendix B. Reservoir Number One was first filled in January 1879. No major post-construction changes have been made to the dam.

i. Normal Operational Procedures. The dam is used for flow regulation and as an emergency water supply by the Metropolitan District Commission of Massachusetts. Because of the reported poor quality of the water in Reservoir Number One, only during periods of a severe emergency would the water impounded by the dam be used. There is a 1mgd or 1.55 cfs bypass at the gatehouse which, by legislative action, is continuously flowing from the downstream side of the gatehouse. Although provisions for the flashboards are in evidence, it was reported that flashboards have not been used for some time. The waste gates are operated during periods of high flow.

1.3 Pertinent Data

The elevation of the spillway crest is reported by the MDC to be 167.60 Boston City Base Datum. Converting this elevation to National Geodetic Vertical Datum (NGVD) by subtracting 5.65 ft. gives an approximate spillway crest elevation of 161.9 NGVD. All other elevations reported herein are based on rough measurements made at the dam site on 29 March 1979, and thus should only be considered approximate.

a. Drainage Area. The total drainage area of the Sudbury River above Reservoir Number One Dam is estimated to be 74.3 square miles. Ground elevations in the watershed vary from a low of about El. 160 near the dam to a high of about El. 700 on Fay Mountain in the Town of Westborough. About 80 percent of the area consists of rolling woodlands. The remaining 20 percent consists of swamps, ponds and reservoirs. Among these, Sudbury Reservoir, Reservoirs Nos. 1, 2 and 3, Ashland, Hopkinton and Whitehall reservoirs are operated by the MDC. Relatively small residential areas are scattered throughout the drainage area, particularly in the northern and eastern parts.

b. Discharge at Dam Site

1. Outlet Works..... Three 5 ft. by 6 ft. waste gates at invert

	El. 150.4 and two sets of 4 ft. by 4.5 ft. gates (two in series each) into Sudbury Aqueduct at invert El. 149.4(total of 10 gates)
2. Maximum known flood at dam site.....	4,500 cfs in August 1955
3. Ungated spillway capacity at top of dam.....	4,600 cfs at El. 171.4
4. Ungated spillway capacity at test flood pool elevation.....	4,530 cfs at El. 175.4
5. Gated spillway capacity at normal pool elevation....	Not applicable
6. Gated spillway capacity at test flood pool elevation...	Not applicable
7. Total spillway capacity at test flood pool elevation...	4,530 cfs at El. 175.4
8. Total project discharge at test flood pool elevation...	18,800 cfs at El. 175.4, excluding flows into waste and into the aqueduct

c. Elevation (ft. above NGVD)

1. Streambed at centerline of dam.....	149.4
2. Maximum tailwater.....	Unknown
3. Upstream portal invert diversion tunnel.....	Not applicable
4. Normal pool.....	161.9
5. Full flood control pool.....	Not applicable
6. Spillway crest (without flashboards).....	161.9
(with flashboards).....	Not applicable
7. Design surcharge - original design.....	Unknown
8. Top of dam.....	171.4
9. Test flood design surcharge.	175.4

d. Reservoir

1. Length of maximum pool.....	3 mi. (Est.)
2. Length of normal pool.....	1 mi. (Est.)
3. Length of flood control pool.....	Not applicable

e. Storage (acre-ft.)

1. Normal pool	600
2. Flood control pool	Not applicable
3. Spillway crest	600
4. Top of dam	3,075
5. Test flood pool	5,150

f. Reservoir Surface (acres)

1. Normal Pool	130
2. Flood control pool	Not applicable
3. Spillway crest	130
4. Top of dam	470
5. Test flood pool	720

g. Dam Embankments

1. Type	Two earth embankments separated by gate house and spillway
2. Length	360 ft. right of gate house, 220 ft. left of spillway
3. Height	22 ft.
4. Top width	20 ft.
5. Side slopes	2 horizontal to 1 vertical, U/S and D/S
6. Zoning	Select fill U/S, gravel D/S
7. Impervious core	Stone masonry core wall
8. Cutoff	Sheet piling driven below core wall at some locations
9. Grout curtain	None
10. Other	Dam constructed in sand and gravel

h. Diversion and Regulating Tunnel. Not applicable

i. Spillway

1. Type	Stone masonry, overflow type with stone masonry apron
2. Length of weir	168 ft.

3. Crest elevation.....	161.9
4. Gates.....	None
5. U/S channel.....	Could not be observed
6. D/S channel.....	Cascade type three-level stone masonry apron, with stone masonry bank protection extending to the Winter Street bridge

j. Regulating Outlets. A plan sketch of the regulating outlets in the gate house is included in Appendix A. As shown on the sketch, page A-6, there are three 6 ft. high by 5 ft. wide waste gates (Gates No. 1, 2 and 3) on the left side of the gate house with an invert elevation of 150.4. It is assumed that the outlets at Gates No. 1, 2 and 3 could be used to lower the reservoir level in case of emergency, although their discharge capacities have not been estimated. A one mgd gate is continuously open, drawing water from wasteway No. 3 and outletting through the gate house sidewall at El. 152.4. All gates are operated manually.

On the right side of the gate house are two intake chambers controlled by two 4.0 ft. high by 4.5 ft. wide sluice gates in series per chamber (Gates No. 6 and 8 and Gates No. 7 and 9). These chambers feed a 6-ft. horseshoe-shaped transmission line which, in turn, connects to the Sudbury Aqueduct. The invert elevations of Gates No. 6, 7, 8 and 9 and the transmission line are at El. 149.4.

A 48-in. diameter pipe from the upper dams enters a concrete chamber to the right of the waste gates at an invert elevation of 149.4. The flow from this chamber can be diverted to the transmission line through a 4-ft. square gate (Gate No. 5) at the right side of the chamber or to the Sudbury River through a 4 ft. square waste gate (Gate No. 4) on the left side of the chamber. The invert elevation of Gates No. 4 and 5 are 149.4.

The upstream wall of the gate house is shown on a record drawing, page B-20. Note that directly above the 48-in. diameter pipe entering the gate house is an 8 ft. high by 5.25 ft. wide opening in the wall which would allow water to freely enter the concrete chamber for the 48-in. diameter pipe. The invert elevation of the opening is El. 162.7 without stoplogs, which is 0.8 ft. above the spillway crest elevation. All inlets on the reservoir wall of the gate house have provisions for stoplogs.

SECTION 2 - ENGINEERING DATA

2.1 Design Data

Certain general design considerations and four record drawings for Reservoir Number One Dam are included in a Boston Water Works report entitled "Additional Supply from Sudbury River, Description of the Work, with Plates", dated 1882. With the exception of a table giving storage capacity of the reservoir at certain elevations, the design information is not detailed and does not include calculations.

2.2 Construction Records

Record drawings and general information regarding the construction materials, construction techniques and sequence of construction are included in the 1882 Boston Water Works report.

2.3 Operation Records

Daily reservoir water surface elevations were the only operational records located during the course of this investigation. The water surface elevations were measured by means of a graduated rod at Gates No. 1, 2 and 3 and recorded at the office of the MDC Sudbury Section in Framingham, Massachusetts.

2.4 Evaluation of Data

a. Availability. A list of the engineering data available for use in preparing this report is included on page B-1. Selected documents from the listing are also included in Appendix B.

b. Adequacy. There was a fair amount of engineering data available to aid in the evaluation of Reservoir Number One Dam. A review of these data in combination with visual examination, preliminary hydraulic and hydrologic computations, considerations of past performance and application of engineering judgement, was adequate for the purposes of a Phase I assessment.

c. Validity. The information contained in the engineering data may generally be considered valid.

SECTION 3 - VISUAL EXAMINATION

3.1 Findings

a. General. The Phase I visual examination of Reservoir Number One Dam was conducted on 29 March 1979. On this day, the upstream water surface elevation was about 0.3 ft. above the spillway crest.

In general, the dam embankments and spillway were found to be in good condition. Some minor deficiencies which require correction were noted.

A visual inspection check list is included in Appendix A and selected photographs of the project are given in Appendix C. A "Site Plan Sketch", page C-1, shows the direction of view for each photograph.

b. Dam. The earth embankments located right of the gate house and left of the spillway are generally in good condition. The grass covered slopes are well mowed, permitting thorough observation. There was no evidence of settlement, lateral movement, seepage or other serious defects. The following specific items were noted:

1. The upstream slopes, Photos No. 1 and 7, are paved with large cut stones. With the exception of minor vegetation in the joints, Photo No. 8, and some low brush growing near the top, the stone paving is in good condition.

2. Deep tire ruts were evident on the crest of the right embankment at the right abutment, Photo No. 7. The crest is also eroded several inches by foot traffic adjacent to the gate house and adjacent to the left spillway training wall.

3. There are four large trees growing at the toe of the right embankment, Photo No. 3. The downstream slope of the left embankment is shown on Photo No. 5. Active, localized erosion of the downstream slopes by foot traffic and runoff is occurring adjacent to the gate house, Photo No. 4, and adjacent to the left spillway training wall, Photo No. 6.

c. Appurtenant Structures. The spillway weir, apron,

sidewalls, discharge channel walls and gate house exterior are all constructed of granite masonry. The granite masonry, in general, exhibits minor loss of mortar from the joints.

Water over the spillway weir and apron prevented a clear view of the joints. However, the weir and apron show no signs of movement or distress. There were approximately 15 rods observed along the crest of the weir, which may once have supported flashboards. No flashboards were observed on 29 March 1979. On 9 of these rods were attached wooden devices called ducks which are used to reduce the noise of the water flowing over the crest. These conditions are shown in Photos No. 2 and 9. The left and right spillway training walls, Photos No. 5 and 8, exhibit only minor loss of joint mortar.

The left spillway discharge channel wall, Photo No. 5, is generally in good condition. The joints of the right discharge channel wall show extensive loss of mortar. The wall is tilted toward the channel at the top, Photo No. 11. There is an indication that soil from behind the right wall has washed through the joints during periods of high water, causing the stone riprap side slope to settle, Photo No. 12.

The gate house is a granite masonry structure with a slate-covered roof and is generally in good condition. The joints at and just above waste ports 1, 2 and 3 show signs of staining and efflorescence, Photo No. 10. The windows are in poor condition and some of the panes are broken. Some of the copper flashing along the edge of the roof has broken off. The exterior of the gate house is shown in Photos No. 1, 2, 4, 7, 8, 9 and 10.

The general condition of the gate house interior could not be evaluated due to the current repairs to the chambers and floor underway and because the deteriorated lighting system was not operative. Boards normally covering the major openings in the interior ground level floor of the structure had been removed. The openings showed signs of reconstruction and repairs underway at the time of the investigation, Photos No. 13 and 14. Aluminum wide flanged sections appear to have been recently placed across four of the openings. Due to the lack of light and a safe means of access, the shafts and chambers below the main floor were not observed during the site visit. However, viewing those shafts from the top

indicated that they are constructed of concrete and the upper regions are in good condition.

There were 9 sets of double-stemmed controls and one single-stem control observed in the gate house, Photos No. 13 and 14. The controls that operate Gates No. 2, 5 and 9 were open on the day of the site visit, while the remaining gates were closed. The single stem control for the 1 mgd (1.55 cfs) gate was also in the open position. Close inspection of the gates was not possible, although some of the gates observed through openings in the main floor appear to be very rusty. None of the gates other than the single stem gate were operated during the site visit. There are indications that the gate controls for Gates No. 1, 2, 3, 4, 5, 8 and the single stem gate are well maintained, while Gates No. 6, 7 and 9 reportedly have not been operated for more than 19 years and obviously have not been well maintained. See the sketch on page A-6 for the various gate locations.

There is a small wooden structure just downstream of the gate house which is in good to fair condition. The porch of the structure, which is access to another water supply gate, is in very poor condition. The porch has been lifted off its foundation at some points, Photo No. 16, and the ground surface beneath it has been scoured.

d. Reservoir Area. Reservoir Number One is generally bordered by wooded residential property, Photo No. 2. The terrain above the shoreline is relatively gentle. There is no significant probability of landslides into the reservoir affecting the safety of the dam. Sedimentation has reportedly not been a problem at the dam site.

e. Downstream Channel. The river below Reservoir Number One Dam flows through Framingham, Wayland, Sudbury, and Concord, where it joins the Assabet River. The two streams then form the Concord River, which flows into the Merrimack River at Lowell. A section of the river, about one mile long, from the dam to Union Avenue was studied for evaluation of flooding impacts of a dam failure. In this section, the river passes under Winter Street, the former Penn Central Railroad tracks, Franklin Street and Union Avenue in Framingham. Characteristics of the bridge openings are summarized below:

Street	Shape of Opening	Dimensions
Winter Street	2 semi-circular	radius: 9.25 ft.
	1 rectangular	length: 20 ft.
		height: 11 ft.

Street	Shape of Opening	Dimensions
Penn Central RR	1 rectangular	length: 58 ft. height: 10.2 ft.
Franklin Street	1 segment of a circle	span: 60 ft. arch length: 66 ft. rise: 11.7 ft.
Union Avenue	1 segment of a circle	span: 55 ft. arch length: 61.3 ft. rise: 11.4 ft.

Upstream of Winter Street, the channel is about 200 ft. wide and about 120 ft. long. The spillway apron is of stone masonry, constructed at three levels, and has a total length of about 40 ft. The stone masonry side walls of the channel are about 6 ft: high. The upstream sides of the three Winter Street bridge openings are shown in Photo No. 15.

Baiting Brook joins the Sudbury River at a distance of about 100 ft. downstream of Winter Street. The Sudbury River at this location flows through an open woodland 400 ft. wide. About 2,000 ft. further downstream, the Sudbury River receives flows from Eames Brook, which is an outlet of Farm Pond. There are several developments, primarily industrial-commercial, along the river banks, particularly downstream of the railroad bridge.

3.2 Evaluation

Based on the visual examination during the site visit on 29 March 1979, the dam and appurtenant structures are generally in good condition, with the exception of minor embankment erosion, the apparent tilting of the right discharge channel wall and the loss of material from behind that wall and the lack of maintenance of the controls for Gates No. 6, 7 and 9. Some renovations to the gate house are currently underway, but at the time of the site visit there was no electric service and the floor over the chamber openings had been removed, creating hazardous conditions for the operator.

The trees noted at the downstream toe of the right embankment do not appear to present a hazard at this time. The porch of the wooden structure immediately downstream of the gate house cannot be considered adequately safe for access to a water supply gate. Otherwise, the minor deficiences noted require remedial action, but should have no immediate effect on performance or safety of the dam.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 Procedures

There are no formal operational procedures other than keeping the 1 mgd bypass at the gate house continually flowing, since water in the reservoir would be used for water supply only during periods of emergency. The gates are generally operated to regulate flow in the Sudbury River by personnel from the MDC Sudbury Section office in Framingham.

4.2 Maintenance of Dam

There are no established procedures or manuals for inspection and maintenance of the dam. However, the grassed earth embankments are apparently mowed regularly and reportedly examined periodically.

4.3 Maintenance of Operating Facilities

There were no formal maintenance procedures for the operating facilities disclosed. However, regular examinations are reportedly performed, and routine maintenance such as clearing debris from the spillway is carried out on a demand basis. Modification to the removable flooring in the gate house was underway at the time of the site visit. All gate controls in the gate house are hand-operated and well maintained, except for the controls to Gates No. 6, 7 and 9, which are not commonly used. Only the operation of the 1 mgd bypass gate was demonstrated on 29 March 1979. Electric power within the structure was not operative.

4.4 Description of any Warning System in Effect

There is no warning system or emergency preparedness plan in effect for this structure.

4.5 Evaluation

The owner should prepare an operations and maintenance manual for the dam. The manual should delineate the routine operational procedures and maintenance work to be done on the dam to provide satisfactory operation and minimize deterioration of the facility. For example, all control gates should be operated periodically.

Since failure of the dam would probably cause loss of life and extensive damage downstream, the owner should also prepare a formal emergency preparedness plan and warning system.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 Evaluation of Features

a. General. The dam consists of two earth embankments with cement mortared stone masonry core walls and a spillway structure of cement mortared stone masonry. A gate house is located at the right abutment of the spillway. The present purpose of the dam is to provide flow regulation and water storage for emergency water supply to the metropolitan area of the City of Boston. Operation of the reservoir is coordinated with that of several other upstream reservoirs which are part of the MDC system. Part of the flow from Wachussett and Quabbin Reservoirs is diverted into the drainage basin through various aqueducts to supplement flow into the Sudbury Reservoir.

The existing multiple reservoirs and relatively large swamps within the drainage basin will have the effect of reducing the intensity of any flood flows. A significant spillage occurs from the reservoir during the wet season.

b. Design Data. No detailed hydrologic or hydraulic design data were available for this dam site.

c. Experience Data. Historical records of the maximum flows could not be obtained. A hydraulic profile of the Sudbury River in a report prepared for the MDC in 1975 by C.E. Maguire, Inc. indicates a maximum flow of 4,500 cfs during an August 1955 storm. The water surface elevation in the reservoir at that time was, as scaled from the profile, about El. 170 (NGVD). During a January 1979 storm, a maximum water surface level of El. 164.5 (NGVD) was recorded in the reservoir. Reportedly, a street along Baiting Brook leading towards Framingham Center was flooded and blocked to traffic during the January 1979 storm.

d. Visual Observations. At the time of the site visit, about 0.3 ft. of water was flowing over the 168 ft. long spillway. Top of the dam was measured to be about 9.5 ft. above the spillway crest. Flow into the downstream channel was only passing through the rectangular opening near the right abutment of the Winter Street bridge. A reverse flow, originating at the confluence of

Baiting Brook with the Sudbury River, was passing through the two semi-circular openings at the bridge into the stilling basin of the dam.

Downstream sections were observed and measured at the Winter Street, Railroad, Franklin Street and Union Avenue bridges. Brief data on the bridge openings are presented under Section 3.1 e, Downstream Channel.

e. Test Flood Analysis. Based upon the Corps of Engineers guidelines, the recommended test flood for "intermediate" size dams having a "high" hazard potential is the PMF (Probable Maximum Flood). The PMF was determined using Corps of Engineers Guidelines for Estimating Maximum Probable Discharge in Phase I Dam Investigations. A peak flow rate of 270 cfs per square mile was determined for the upper Sudbury River basin, based on New England Division, Corps of Engineers guidelines dated March 1978. The resulting PMF or the spillway test flood inflow for the 74.3 square mile drainage area is about 20,000 cfs.

Surcharge-storage routing was performed through Reservoir Number One using the stage-discharge and area-volume curves shown in Appendix D. Flows through the outlets to waste and to the water supply system were ignored for this evaluation.

The test flood outflow, estimated to be 18,800 cfs, would occur when the water surface level in the reservoir is at about El. 175.4. This is 4 ft. above the top of the dam. A preliminary study of the test flood hydraulic profile in the downstream channel, in Appendix D, indicated that the tailwater elevation would be at El. 171.5 and that a large area downstream of the dam would be flooded.

The existing spillway capacity is about 24 percent of the test flood outflow because discharge from the dam is controlled by restrictions in the downstream channel, as shown on the preliminary hydraulic profiles, page D-9. If the downstream channel capacity was adequate, the spillway capacity would be about 92 percent of the test flood outflow.

f. Dam Failure Analysis. Based on Corps of Engineers Guidelines for Estimating Dam Failure Hydrographs, assuming that a failure would occur along 40 percent of the length at the mid-height of the dam structure, and taking the tailwater curve into account, the peak failure outflow is esti-

mated to be 18,200 cfs. The downstream channel capacity is not adequate to carry this flow without flooding its banks to a depth ranging from about 5 ft. near Union Avenue to about 9 ft. near the railroad bridge. The flow over the spillway prior to a failure would flood the same areas by 2.5 ft. and 5 ft., respectively.

On the left bank, about 15 acres of residential area around Baiting Brook and about 50 acres of residential area immediately south of Framingham Center, including a school complex, would be affected. On the right bank, at least three manufacturing plants, several commerical outlets and the Bowditch Field Athletic Facilities would be flooded. The impact area is delineated on the map on page vii.

In conclusion, in the event of a dam failure, potential for loss of lives exists and excessive residential, institutional, industrial and commercial property damages are expected to occur. Therefore, the hazard potential classification for this dam is considered high, in accordance with Corps of Engineers guidelines.

SECTION 6 - STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. Visual Observations. There was no visual evidence of settlement, lateral movement or other signs of structural instability in the earth embankments. No indications of seepage through the embankments were observed.

There was no visual evidence that movement or distress in the spillway weir, apron, training walls, discharge channel walls and gate house has taken place, other than the tilting of the right discharge channel wall and the loss of material from behind that wall.

b. Design and Construction Data. Design and construction data in the form of narrative descriptions and record drawings of the original construction of the spillway structure, discharge channel walls and substructure of the gate house are available. Design data in the form of record drawings of the original construction of the superstructure reportedly exist, but could not be located during the site visit. Review of the drawings indicates that the dimensions and configurations of the embankments and spillway are consistent with typical dams of this size. Apparently no observed movement or distress has occurred since the construction of the dam, and it would be reasonable to conclude that the embankments and spillway would be adequately stable under normal static loading conditions in the absence of significant seepage.

c. Operating Records. Operating and maintenance records for the facility are routinely summarized in monthly reports which are located at the Metropolitan District Commission Headquarters, 20 Somerset Street, Boston, Massachusetts and at the office of the Superintendent of Dams at the MDC Sudbury Section office in Framingham, Massachusetts. There are no records which would indicate the magnitude or the nature of past structural movements, if any. There are no records of uplift water pressures or other information from field instrumentation to aid in the evaluation of structural stability.

d. Post-Construction Changes. The present embankments, spillway and gate house were completed in 1878.

Since that time, there have been no major alterations to the dam. The spillway was repointed in 1956.

e. Seismic Stability. This facility, in accordance with recommended Phase I guidelines, is located in Seismic Zone 2 and does not warrant seismic analysis.

SECTION 7 - ASSESSMENT, RECOMMENDATIONS AND REMEDIAL MEASURES

7.1 Dam Assessment

a. Condition. The visual examination of Reservoir Number One Dam revealed that the structure was in good condition. There were no signs of structural failure or other conditions which would warrant urgent remedial action. Several minor deficiencies were noted.

Based on the results of computations included in Appendix D and described in Section 5, the spillway is not capable of passing the test flood, mainly because the downstream channel conditions control the amount of discharge from the dam. The PMF test flood outflow of 18,800 cfs (inflow 20,000 cfs or 270 csm) would overtop the dam by about 4 ft. With the water level at the top of the dam, the total spillway capacity is 4,600 cfs, which is 24 percent of the test flood outflow. If the downstream channel capacity was adequate, the spillway capacity would be about 92 percent of the test flood outflow.

b. Adequacy of Information. This evaluation of the dam is based primarily on visual examination, approximate hydraulic and hydrologic computations, consideration of past performance, review of available engineering data, and application of engineering judgement. Generally, the information available or obtained within the scope of this investigation was adequate for the purposes of a Phase I assessment. However, it is recommended that additional information on the condition of the spillway weir and apron be obtained.

c. Urgency. The recommendations for additional investigations and remedial measures outlined in Sections 7.2 and 7.3, respectively, should be undertaken by the Owner and completed within two years after receipt of this report.

d. Need for Additional Investigation. An additional investigation should be performed by the Owner as outlined in Section 7.2.

7.2 Recommendations

It is recommended that the Metropolitan District Commission, owner of the dam, assign or engage a registered

professional engineer to observe the dam at a time when there is low or no flow over the spillway to 1) assess the condition of the granite masonry spillway weir and downstream apron and 2) the outlet chambers. If indications of seepage are observed, the Owner should then implement corrective measures.

7.3 Remedial Measures

Although the dam is generally in good condition, it is considered important that the following items be accomplished:

a. Operation and Maintenance Procedures. The following remedial measures should be undertaken by the Owner:

1. Repair the tire ruts in the earth embankment at the right abutment of the dam and the locally eroded areas adjacent to the gate house and the left spillway training wall.

2. Repoint granite masonry on the downstream face of the spillway weir and other walls where necessary.

3. Repair and maintain the gate house to protect the contained equipment, ensure safety of personnel, ensure that equipment is operative and minimize storm leakage into the structure. As a minimum, electric service should be restored to the structure, floor planks placed over open chambers and windows, roof flashing repaired or replaced, and gates examined.

4. Repair the right wall of the discharge channel and the adjacent side slope. It is recommended that the granite masonry joints of the slope be grouted.

5. Repair, for the safety of the operating personnel, the wooden porch of the structure which houses a water supply gate.

6. Prepare an operations and maintenance manual for the dam. The manual should include provisions for annual technical inspection of the dam and for surveillance of the dam during periods of heavy precipitation and high reservoir water levels. The

procedures should delineate the routine operational procedures and maintenance work to be done on the dam to ensure satisfactory operation and to minimize deterioration of the facility.

7. Because the dam is classified as having a "high" hazard potential, develop a written emergency preparedness plan and warning system to be used in the event of impending failure of the dam. The plan should be developed in cooperation with local officials and downstream inhabitants.

7.4 Alternatives

Not applicable.

APPENDIX A - INSPECTION CHECK LIST

VISUAL INSPECTION PARTY ORGANIZATION

NATIONAL DAM INSPECTION PROGRAM

Dam: Reservoir Number One

Date: 29 March 1979

Time: 0830-1130

Weather: Cloudy, 40°F, occasional light drizzle

Water Surface Elevation Upstream: El. 162.2 (0.3 ft. above top of spillway weir)

Stream Flow: Moderate

Inspection Party:

Peter L. LeCount	- Soils/Geology
Richard A. Brown Haley & Aldrich, Inc.	
A. Ulvi Gulbey	- Hydraulic/Hydrologic
Joseph E. Downing	
Robert P. Howard Camp, Dresser & McKee, Inc.	- Structural/Mechanical

Present During Inspection:

John Slocum, Sub-foreman
Steve Kach
MDC Sudbury Section

VISUAL INSPECTION CHECK LIST
NATIONAL DAM INSPECTION PROGRAM

DAM: Reservoir Number One DATE: 29 Mar. 79

AREA EVALUATED	CONDITION
DAM EMBANKMENTS (RIGHT AND LEFT)	
Crest Elevation	Approximately El. 175.4 NGVD, 9.5 ft. above spillway crest
Current Pool Elevation	Approximately El.162.2, 9.2 ft. below top of embankment
Maximum Impoundment to Date	Approximately El. 170.0 in August 1955
Surface Cracks	None observed
Pavement Condition	Not applicable
Movement or Settlement of Crest	None evident
Lateral Movement	None evident
Vertical Alignment	Looks good
Horizontal Alignment	Looks good
Condition at Abutment and at Concrete Structures	Wheel ruts in grass at right abutment; approximately 0.3 ft. erosion of the crest at Gatehouse entrance; apparent erosion of embankment slopes behind walls at ends of spillway
Indications of Movement of Structural Items on Slopes	No structural items on slopes
Trespassing on Slopes	Foot traffic with some slope erosion next to gatehouse
Animal Burrows in Embankment	None observed
Vegetation on Embankment	Grass, generally in good condition except where local erosion, some brush at top of riprap and in joints
Sloughing or Erosion of Slopes or Abutments	Local erosion (few inches) close to gatehouse and training walls
Rock Slope Protection - Riprap Failures	Rock slope paving in good condition
Unusual Movement or Cracking at or near Toes	None observed
Unusual Embankment or Downstream Seepage	None observed

VISUAL INSPECTION CHECK LIST
NATIONAL DAM INSPECTION PROGRAM

DAM: Reservoir Number One DATE: 29 Mar. 79

AREA EVALUATED	CONDITION
Piping or Boils	None observed
Foundation Drainage Features	None known; on right side pipe enters catch basin at toe from direction of dam
Toe Drains	None known
Instrumentation Systems	None known
OUTLET WORKS - SPILLWAY WEIR, APPROACH AND DISCHARGE CHANNELS	
a. Approach Channel	Not applicable. Spillway is fed directly from reservoir
b. Weir and Training Walls	
General Condition	The weir, apron and training walls are constructed of granite masonry and are in good to excellent condition, with some minor loss of joint mortar
Rust or Staining	Minor
Spalling	None observed
Any Visible Reinforcing	Not applicable
Any Seepage or Efflorescence	None observed
Drain Holes	None observed
Flashboards	15 rods observed along crest but no flashboards in place observed. Wooden ducks on 9 of the rods
c. Discharge Channel	
General Condition	Split channel to bridge outlets in good condition
Channel Walls	The left and right channel walls are constructed of granite masonry. The left wall is in good to excellent condition, with some minor loss of joint mortar. The right discharge channel wall shows signs of extensive loss of mortar and is tilted towards channel. Riprap side slope has settled

VISUAL INSPECTION CHECK LIST
NATIONAL DAM INSPECTION PROGRAM

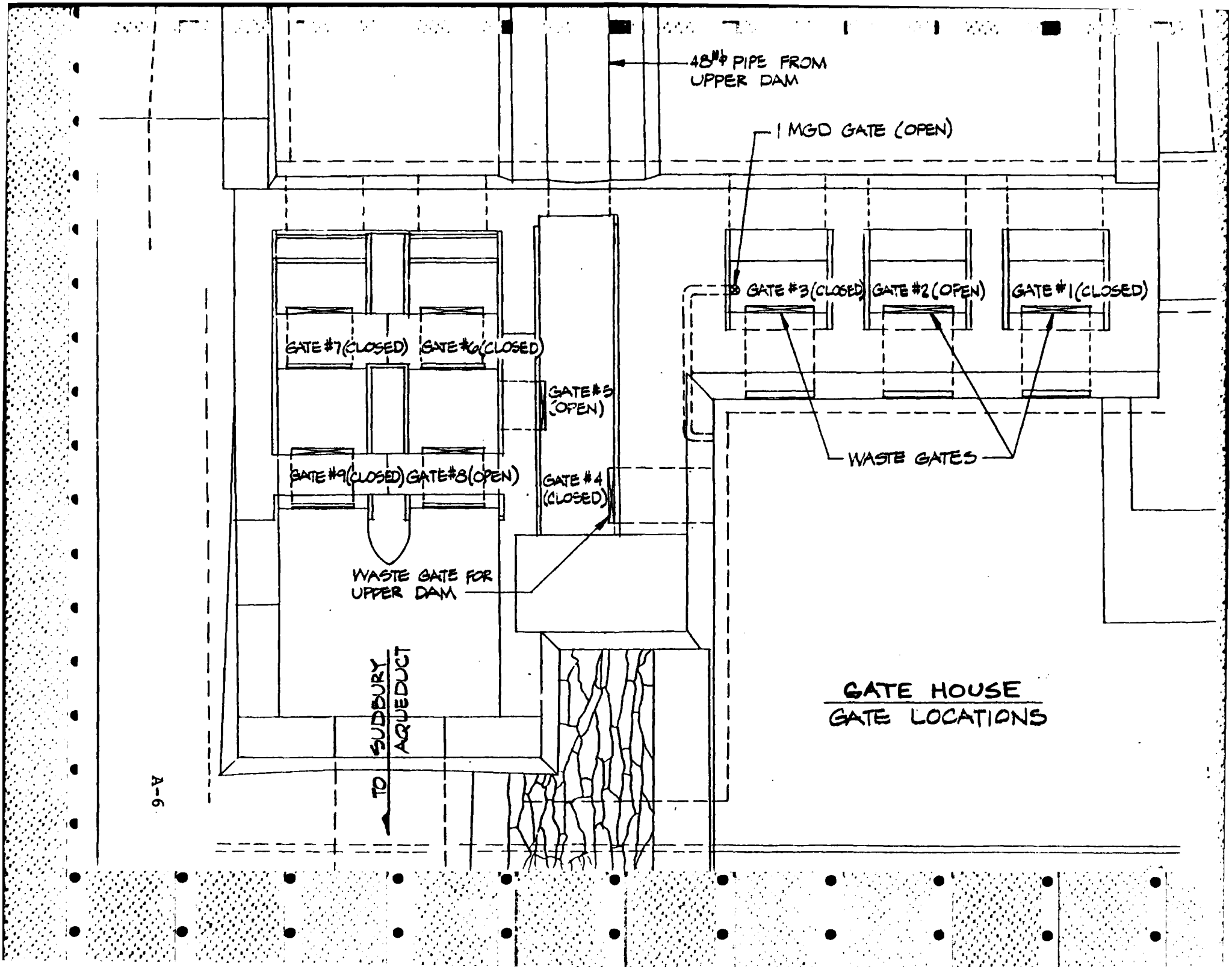
DAM: Reservoir Number One DATE: 29 Mar. 79

AREA EVALUATED	CONDITION
Loose Rock Overhanging Channel	None observed
Trees Overhanging Channel	None upstream of bridge
Floor of Channel	Right channel submerged, left channel slightly submerged and shows some minor vegetation
Other Obstructions	None observed
OUTLET WORKS - GATEHOUSE	
a. Concrete and Structural	
General Condition	Stone masonry structure with wood trussed slate-covered wooden roof in good condition. Windows are in poor condition with some panes broken. Roof flashing is good to poor with some broken off and needing repair. General condition of interior of superstructure not evaluated due to current repairs and modifications underway
Conditions of Joints	Good
Spalling	None observed
Visible Reinforcing	None observed
Rusting or Staining of Concrete	None observed
Any Seepage or Efflorescence	Minor staining and efflorescence at masonry joints above ports 1, 2 and 3
Joint Alignment	Good
Unusual Seepage or Leaks in Gate Chamber	Minor seepage through the 48-in. dia pipe from upper dam. Flow diverted through gates No. 5 and 8 to the transmission line
Cracks	None observed
Rusting or Corrosion of Steel	None observed
Removable Flooring	Wood flooring over openings removed. Repairs underway with the placing of new aluminum wide flange members at all floor openings

VISUAL INSPECTION CHECK LIST
NATIONAL DAM INSPECTION PROGRAM

DAM: Reservoir Number One DATE: 29 Mar. 79

AREA EVALUATED	CONDITION
b. Mechanical and Electrical	
Air Vents	None observed
Float Wells	None observed
Crane Hoist	None observed
Elevator	Not applicable
Hydraulic System	Not applicable
Service Gates	Presently not in use and, as observed from operating floor, badly rusted. Gate operators not adequately maintained. Gates 5 and 8 open
Emergency Gates	Gates, observed from operating floor, badly rusted. Gate operators appear to be maintained. Gate 2 open
Other Gates	1 mgd gate open and flowing
Lightning Protection System	None observed
Emergency Power System	None observed
Wiring and Lighting System in Gate Chamber	Not operative
OTHER STRUCTURES	
General Condition	Small wooden structure downstream of control tower in good to fair condition. The porch of this structure is access to the No. 10 gate and is in very poor condition


48"ϕ PIPE FROM UPPER DAM
1 MGD GATE (OPEN)
GATE #3 (CLOSED)
GATE #2 (OPEN)
GATE #1 (CLOSED)
GATE #7 (CLOSED)
GATE #6 (CLOSED)
GATE #5 (OPEN)
GATE #9 (CLOSED)
GATE #8 (OPEN)
GATE #4 (CLOSED)
WASTE GATES
WASTE GATE FOR UPPER DAM
TO SUDBURY AQUEDUCT
GATE HOUSE
GATE LOCATIONS
A-6

APPENDIX B - ENGINEERING DATA

LIST OF AVAILABLE DATA
RESERVOIR NUMBER ONE DAM

Document	Contents	Location
Boston Water Works, Additional Supply from Sudbury River, Description of the Work, with Plates, 1882	Report on the design and construction of Reservoirs Nos. 1, 2 and 3. Included in Appendix B are the specific details and drawings related to Reservoir No. 1	MDC Sudbury Section, 311 Hollis Street, Framingham, MA 01701 and page B-2
State inspection report, Framingham Dam No. 4-9-100-3, 25 July 1973	Inspection report and description of dam	Mass. Department of Environmental Quality Engineering, Division of Waterways, 100 Nashua Street, Boston, MA 02114 and page B-13
Operation records	Reservoir levels	MDC, 20 Somerset Street, Boston, MA 02108
"Repairing Spillways of Sudbury Dam in Southborough and Dams No. 1 and 2 in Framingham", MDC Contract No. 229, 1956	Contract documents for repointing of spillways (no modification of existing structures)	MDC, 20 Somerset Street, Boston, MA 02108
A Study of the Upper Sudbury River Watershed for the Metropolitan District Commission, by C.E. Maguire, Inc., Waltham, MA, 1975	Alternative schemes for MDC Water Supply system	MDC, 20 Somerset Street, Boston, MA 02108

BOSTON WATER WORKS.

Office Water B
April 18

ADDITIONAL SUPPLY

FROM

SUDBURY RIVER.

DESCRIPTION OF THE WORK,

WITH PLATES.

BOSTON:
ROCKWELL AND CHURCHILL, CITY PRINTERS,
No. 39 ARCH STREET.
1882.

GENERAL DESCRIPTION.

The general features of the Sudbury-River works, although described in former reports, must be briefly alluded to for the better understanding of what follows.

The portion of the water-shed of Sudbury River utilized by the city is situated in the towns of Marlborough, Northborough, Westborough, Southborough, Upton, Hopkinton, Ashland, and Framingham.

The river, below the point where the water is diverted, flows through Framingham, Wayland, Sudbury, and Concord, where it meets the Assabet. The united streams form then the Concord River, which flows into the Merrimac at Lowell.

The extent and character of the water-shed, the quality of the water, the expected yield of the river, its variations of volume, etc., are described elsewhere in this paper.

The question of the amount of storage necessary to secure to the city a sufficient supply is discussed at length in City Document No. 29, 1873, extracts of which have been given.

It must be remembered that, there being a connection between the Sudbury-River conduit and Lake Cochituate, the latter will be used as a storage reservoir for the waters of the former.

It has been estimated that storage reservoirs would be necessary on Sudbury River with a capacity of 4,900,000,000 gallons, to give to the city, in the dryest year, a constant supply of 40,000,000 gallons per day.

Such an amount of water not being required at present, three reservoirs only have been built; their capacity, with that of Farm Pond, is about 2,000,000,000 gallons, and they are intended to give, in a dry year, a supply of 20,000,000 gallons per day.

The works, as constructed, can be divided in three main parts: —

First. Three storage reservoirs, in the water-shed of Sudbury River, with their respective dams; also, some of the highways and bridges ordered by the County Commissioners of Middlesex, to take the place of those which were interfered with by the flowage of the reservoirs.

Second. A conduit, conveying the water from the lower dam to Farm Pond; also, all the work necessary to improve Farm Pond and to protect it from pollution and from the freshets of Sudbury River.

Third. The main conduit from Farm Pond to Chestnut-Hill Reservoir, and its direct connection with the city distribution.

STORAGE RESERVOIRS.

Sudbury River has two principal branches, which unite in Framingham in the lower storage reservoir. The main branch rises in the hilly districts of Hopkinton and of Westborough, but flows afterwards through a large extent of low and swampy lands, which are probably the chief cause of the characteristic yellow tinge of the water.

The sources of the other branch of the river, Stoney Brook, are in Marlborough and Southborough, and the general character of the water-shed is more hilly; the stream consequently rises and falls quicker than the other branch; in summer time its flow is comparatively smaller and in freshets time it is much larger in proportion to the area of its water-shed. In the freshet of March 26 and 27, 1876, the largest on our record, the flow of Stoney Brook was equal to that of the other branch, the water-shed of which is about double. The water of Stoney Brook has a lighter color than that of the main branch.

A very large proportion of the area of the whole water-shed is covered with wood, and, outside of the districts occupied by the thickly settled portions of the towns, its character is generally agricultural.

The position of all the proposed storage reservoirs was determined from the surveys made in 1872. With the exception of a change in the location of Dam No. 2, the three lower storage reservoirs have been built according to the indications of the original plan.

One of the reservoirs, No. 2, is located on the main branch of Sudbury River, partly in Framingham and partly in Ashland; another, No. 3, is in the valley of Stoney Brook; the lowest reservoir, No. 1, which covers the point of confluence of the two streams, unites their waters before they are conveyed to Farm Pond.

The dams of the Reservoirs No. 2 and No. 3 being built at points where Reservoir No. 1 is yet several feet in depth, a large amount of shallow flowage is avoided which would otherwise take place if the waters of the lowest reservoir were permitted to extend without interruption to their extreme limits.

The general plan of the storage grounds presents, consequently, an uninterrupted triangular group of reservoirs, with the dam of Reservoir No. 2 and the dam of Reservoir No. 3 located respectively 4,800 and 5,200 feet above the lowest dam.

Early in the period of investigation of Sudbury River it was thought that one of its principal advantages was the independent character of its two main valleys, each of which could be used by itself as a separate source of water supply; it was then proposed, the dams being comparatively little distant from one another, to connect them by a wooden conduit.

In 1877, however, the price of iron being unusually low, the Water Board (on June 26, 1877) voted to lay instead a 48-inch cast-iron pipe.[1] By its means and by an elaborate arrangement of chambers and gates in the gate-houses of the dams, the water from each of the two branches can be sent to the city independently of the other, and, if one of the upper reservoirs must be emptied for cleaning or other purposes, its contents can be sent into the river below Dam No. 1 without interfering with the city's supply, which would, in the same time, be maintained from the other branch through Reservoir No. 1.

Any one familiar with the vegetable formations or other causes which, from time to time, impair temporarily the purity and taste of reservoir water, will see that the arrangement above described may be found of great value. The advantage of this disposition has already been practically illustrated. Owing to an unusual growth of *algæ*, Reservoir No. 3 was separated during the summer and fall of 1879 from the city's supply. During

[1] The price paid for that pipe, which was only one inch in thickness, was $30.00 per ton delivered on the ground at Framingham Centre.

the larger portion of the present year (1880), and for the same reasons, Reservoir No. 1 was permanently and Reservoirs Nos. 2 and 3 alternately disconnected from the city's supply. At such times of the year as the use of the pipes would be likely to be resorted to, the flow of the river is not large, and it is probable that the whole of it from either of the branches could be passed through the pipe, if needed.

The upper part of the water-shed shows some indications of ledge; in its middle and lower parts rock (generally a coarse-grained syenite) crops out in many places and probably underlies the alluvial deposits at no great depth.

In the valleys where the three dams were to be located, clay is never found, but there exist extensive strata of gravel and sand, from the coarsest gravel to the finest of quicksand, showing marks of very irregular, if any, stratification. It became consequently necessary to ascertain the nature and position of the various strata; no definite plan could be decided upon for the foundations of the dams until a full knowledge of the underground formation was obtained.

The natural position of the dams being somewhat indicated by the configuration of the ground, some rod-soundings were made to reconnoitre and to determine the best locations for deeper borings, which alone could give reliable indications.

The borings were made with 5-inch cast-iron pipes, which were driven to various depths, extending in several cases to more than 60 feet; notes were taken of the various strata through which the sounding apparatus was penetrating, and in order to have a correct idea of the perviousness of the ground, the water-bearing capacity of the strata was frequently tested by pumping from the pipe.

The indications given by these soundings were of great value, but in some cases the strata of gravel and sand were so much broken that the results of the soundings were reliable to a certain extent only, and new ones were wanted as construction was progressing. In each case the samples obtained by boring were disposed in large glass tubes on a scale of one inch to one foot of depth. These tubes, arranged according to the respective position of the corresponding soundings in the valley, furnished, better than any drawing, the indications needed for locating and for designing the foundations of the dams.

All the work done for the additional supply has been, when practicable, done by contract, but, owing to the uncertainty of the ground through which the foundations of the dams were to be built and to the fact that extensive changes from the original design (especially in regard to the depth of excavation in the bed of the streams) might be found necessary during the progress of the work, it was found advisable to build the foundations of the dams, as high as the surface of the ground, by day labor. The City Council authorized the Water Board to do so; and on November 11, 1875, the latter passed a vote to that effect, instructing the City Engineer to organize the work accordingly.[1]

The work to be done being of magnitude, it was organized with some care; a superintendent, acting under the direction of the engineering force, was appointed, and a foreman put at the head of the work to be done at each dam.

A purchasing agent (performing also the duties of paymaster), appointed by the Water Board, furnished all the supplies needed; timber, cement, stone, and other materials were bought; pumps, derricks, steam-engines, and other implements were hired, and capacious barracks were erected to provide boarding accommodations for the workmen. The large quantities of stone needed for the foundations were procured by contract from the neighboring quarries.

The work for the foundations commenced in the summer of 1876. It was completed the last day of the year for Dam No. 1, and at the end of the working season of 1877 for Dam No. 2 and Dam No. 3.

The general mode of construction is the same for the three dams. The material at

[1] This vote included also the construction of Section 1 of the main conduit.

the location of each of them being of a pervious nature it was not thought sufficiently safe to erect the main body of the dam on comparatively shallow foundations, and to attempt to secure the imperviousness of the dam by means of embankments formed of the materials found on the ground. It was judged necessary to build in the middle of the embankments an impervious wall, and to produce it, as well as the foundations of the overflows and of the gate-houses, to such a depth in the ground as to prevent any injurious action of the water percolating through the underground strata. Clay not being found in the neighborhood it was decided to resort, for the centre walls, to the use of stone masonry laid in cement mortar. A wall built in this manner in porous ground, although not so impermeable as a puddle bank, is thought to present a greater guarantee of safety if water percolates along its faces and around its ends and bottom under the influence of the head in the reservoir.

The masonry foundations of the gate-house, of the overflows, and of the centre walls, are built on gravel and sand, except at Dam No. 2, where the overflow, the gate-house, and a small length of the centre walls on each side of the central structure, repose directly on rock. Plates 3, 7, and 8 show the formation of the ground at the location of the dams.

Each dam is composed of three different parts, viz.: —

First. A waste overfall made of rubble masonry laid in mortar, and extending to the bottom of the foundation (sheet-piling has been frequently driven in front of the foundations). The portion of the overfall which is above the surface of the ground is faced and capped with cut granite; on the up-stream side of the overfall an earth embankment is built against it, made of as compact material as could be found in the neighborhood; the toe of this embankment is protected by sheet-piling. Below the overfall an apron is built of heavy stones of various sizes laid dry, reposing on stone masonry laid in mortar near the overfall and on a timber platform further from it. The end of the apron is protected by a line of sheet-piling. The masonry foundation of the apron being shallower than that of the overfall, care has been taken to keep them entirely independent and without any bond.

Second. A gate-chamber adjacent to the overfall, built of cut granite on a rubble-stone foundation, and containing the iron gates necessary for the control of the water contained in the reservoir. A special chamber is provided for the 48-inch iron pipe connected with the other dams. Above and below the gate-house an apron is provided, built similarly to that of the overfall.

Third. Earth banks, separated from the overfall and from the gate-house by wing-walls built of rubble-stone masonry faced with cut granite.

The banks contain a centre wall of rubble stone laid in cement mortar, and extending deeply into the ground.

Wherever the natural ground beyond the banks is porous, and forms a comparatively narrow ridge, the wall is extended through it to a considerable depth. Sheet-piling has also been used, from time to time, in connection with the centre walls.

From what precedes it may be seen that the timber and masonry work of the gate-chamber, of the overfall (including their foundations), and of the walls of the embankments form together across the valley a continuous obstacle to the passage of the water. Whenever sheet-piling has been resorted to, in the construction of the dams, in connection with masonry, it has been driven or placed first and the masonry built to it. When trenches were sheeted to support the ground during the construction of the deep masonry foundations every vestige of the timber was removed, and the space between the

masonry and the side of the trench was refilled with the best material that could be found, thoroughly wetted.

The earth banks on the up-stream side were formed with the best materials (often mixed together) to be found on or near the grounds, laid in thin layers, wetted, and well compacted.

It being expected, owing to the nature of the materials used, that some percolation would take place through the banks and through the large area of centre walls exposed to the pressure of the water, all the banks on the down-stream side were formed of gravel, which cannot be disturbed by such percolation.

In the summer of 1877, James B. Francis, C.E., in behalf of the County Commissioners of Middlesex, made an examination of the foundations of the dams then being built. As his report to the Commissioners touches the most important points in reference to these structures, an extract from it may be found interesting: —

The masonry, pilings, puddling, and embankments, where they can be seen, are of excellent quality, and have all been done by the day for the purpose of securing the best quality of work.

The three dams are all on the same general plan, namely, the overfalls for the discharge of surplus water in freshets, and the gate-houses containing the passages for drawing water for the supply of the city, are of granite masonry laid in hydraulic cement. The embankments on each side of the overfalls and gate-houses are of earth with centre walls of similar masonry. The overfalls, gate-houses, and part of the centre-walls of the embankments of Dam No. 2 are founded on the rock, the remaining parts of the centre-walls of this dam and the whole of the masonry in Dams Nos. 1 and 3 are founded on sand or gravel. The rock at Dam No. 2 is of a granite character and at a considerable depth, and there can be no question as to its affording a perfectly safe foundation. As I am informed by the resident engineer, the masonry at all the dams, where not founded on rock, is on compact sand or gravel. These materials afford a perfectly safe foundation so long as they are not acted upon by water; this has been guarded against in these dams by the great depth to which the masonry extends, and also by sheet-piling, puddle, and aprons of timber and granite, and I have no doubt, from all I could gather from my own examination and the information furnished by the resident engineer, that the foundations are sufficient to provide for all the contingencies that there is any probability of their being subjected to.

The dimensions of the masonry and embankments, as represented on the plans exhibited, in my opinion are amply sufficient.

RESERVOIR NO. 1.

This reservoir, in its broadest part, covers the point of confluence of the two branches of Sudbury River;[1] it extends thence towards Dams No. 2 and No. 3, which limit its extent up-stream, in two separate arms of irregular form; these two arms are connected together by a continuous narrow run; some parts of the shore at various points are deeply indented.

Reservoir No. 1 being situated on the borders of the thickly settled portions of Framingham Centre, the estates which have been interfered with are more valuable than ordinary farms, and the amounts paid to their owners on account of damages have been in some instances very large; one small water privilege connected with the Bullard place has been destroyed; another on the land of W. G. Lewis, the fall of which has only been reduced, had little, if any, importance. The same owner claimed the partial destruction of a small privilege used for working water-rams.

At some points, where the flowage would have been very shallow, excavations were made to secure a depth of four feet at ordinary high-water mark, and the material excavated was used for filling a part of the shallow land. Such has been the case for a small portion of W. G. Lewis' land, north and south of Salem street, of the Homer farm, of the land formerly owned by F. C. Browne, and of the land of R. W. Whiting.

[1] "It (Sudbury River) is formed by the union of South Branch, commonly known as Hopkinton River, and of Stoney Brook; and, in the early records, only that portion below where the two branches unite was called Sudbury River." (*History of Framingham, by Josiah H. Temple.*)

Large quantities of loam at various points, near the water's edge, have also been removed by the citizens of Framingham.

The upper part of the reservoir, near Dam No. 3, is crossed by a new highway with an iron bridge. This new road having been necessitated by the construction of Reservoir No. 3, with which it is more closely connected, it will be described in the same time as the latter.

Salem street, a county-way, and Lawn avenue, a town-way, had to be raised at different places to conform to the high-water mark of the reservoir.

Salem street, between the Clapp estate, and the (formerly) Bullard place, was raised and straightened to a point 6 feet above the high-water line; a bridge was built, with substantial stone abutments, and the slopes were paved to resist the wash of the water against the embankment.

The adjacent portion of Salem street, from the Bullard place, westward, was subsequently raised slightly in 1879.

(For County Commissioners' orders, etc., see Appendix.)

Lawn avenue was also raised in two places. The more important portion, between W. G. Lewis' and J. Van Praag's, was made in 1877, with a substantial stone culvert, the slopes were paved and fences erected. The alignment, different from the old one, was made to conform to the proposed straightening of the avenue.

Another small portion of Lawn avenue, near M. Welch's house, was raised in 1879, the slopes paved and a fence put up. A new culvert, deeper than the old one, was built across Salem street, opposite the Homer estate, to connect the excavated portions of the reservoir.

All the wood and brush growing on the location of the reservoir was cleared in 1878 to the high-water line.

The depth of Reservoir No. 1, at the dam, is 15.50 feet; its general depth is not considerable, but the configuration of the land is such that the water could not be raised higher without interfering materially with a large area of land and without creating extensive shallows on land now included between the two arms of the reservoir and situated only a few feet above its waters.

Owing to the small amount of fluctuation that can be allowed and to the necessity of maintaining the depth of water as great as possible, the stone crest of the dam has been built 21 inches below the ordinary high-water mark which is to be kept by the means of movable flash-boards.

The extreme high-water mark, from which the seizures of land have been regulated, is 3.25 feet above the crest of the masonry of the dam.

The capacity of the reservoir when the water is even with the top of the flash-boards (ordinary water mark) is 288,400,000 gallons. (For the capacities corresponding to various heights of water in the reservoir, see Appendix.)

Reservoir No. 1 was filled for the first time at the end of January, 1879, and emptied again from April 14 to 17, to allow the contractors to work at Dam No. 2. The reservoir was filled again in December, 1879.

DAM NO. 1.

The plans and specifications for Dam No. 1 were approved by the County Commissioners of Middlesex on March 7, 1876.

Dam No. 1, which forms the reservoir just described, extends in a straight line in a north-easterly direction across the valley of Sudbury river at a small angle with Winter street. (For its stationing, etc., see Appendix.)

The gate-chamber is at the southern end of the overflow.

Plate 13 gives a correct idea of the nature of the ground through which the dam was built.

At the southern end the material in which the centre wall is built is compact and impervious, although containing no clay, or a very small portion of it; it was composed of "cemented gravel or hard-pan," and hard to pick. A little further towards the river the gravel deposit below the surface loam increased in depth, and the foundation was produced into a hard, compact sand mixed with gravel. As the excavation reached the bed of the river, the material, a mixture of gravel and sand in irregular strata, was of a more pervious character; the masonry foundation was built to an increased depth, and its base was protected by sheet-piling, placed or driven, as could be done more conveniently, into a stratum of compact sand. A small pocket of quicksand was found under the north-east corner of the conduit chamber. Further in the bed of the river a large boulder or point of ledge, indicated on the section, Plate 13, was found imbedded in the sand and gravel. It was tested by drilling to a depth of four feet, and, being found too large to be removed without danger of loosening the surrounding material, the masonry of the overflow was built on it. As, however, it was feared that there might be an unequal settlement between the portions of masonry built on this rock and on the adjoining material, which was of a more yielding nature, the foundation was built separately on the rock and on the adjacent spots, leaving between them a V-shaped space. After these different pieces of masonry, built as high as the surface of the ground, had been allowed to stand independently for some time, they were connected together. Beyond that point the masonry foundation was built in a stratum of coarse sand, bearing little water, and protected by sheet-piling driven into a more compact stratum. Beyond the overflow the centre wall is built through a deep superficial stratum of gravel into a body of fine, compact sand.

The amount of water which had to be pumped during construction was sometimes very considerable, and the laying of the foundation required in many places much care and watchfulness. During the last weeks of December, 1876, the weather being very cold, it was thought desirable not to leave for another season the small amount of work remaining to be done by day labor, and some preparations were made to prevent the work from being injured by the cold weather; the water and sand used for the masonry were heated, the stones were submitted, before being laid, to a jet of steam; the work was carefully covered, as soon as laid, with hay mattresses, and advantage was taken of the least severe weather to do the earth refilling. The portion of the masonry foundation thus laid is about the junction of the waste overflow, of the north wing-wall, and of the centre wall of the adjoining bank.

This part of the work was examined in the following spring, and was not found in any way inferior to the portions built in more favorable weather.

All the aprons and all the sheet-piling used to protect them were, like the foundations, built by day labor. The aprons were made of heavy stone from two to three feet deep, laid dry below the overfall, and in cement mortar above and below the gate-house; near the main structure they repose on a foundation of rubble masonry laid in cement mortar; further from it they are supported by a timber platform. (For the details of the aprons, sheet-piling, etc., see Plates 14 and 16).

The material used for refilling the trenches, and for forming the up-stream side of the banks, was composed of a mixture of fine sand, of gravel, and occasionally of a little yellow loam; on the northerly embankment more gravel has been used; the most porous gravel has been laid on the down-stream slopes.

The overflow, 11 feet thick and 169 feet long, is capped with heavy cut-granite blocks; its face and those of the wing-walls are formed of granite ashlar, with quarry faces; the gate-chamber is made entirely of cut granite, with the inside faces pointed. (Plates 14, 15, and 16.)

It has been mentioned before that the level of the water in Reservoir No. 1 is regulated by flash-boards. They are 21 inches in height, in 2 rows; they are to be generally in place on the crest, and will be dispensed with in time of freshets. In order to secure their removal beyond a doubt in case of a heavy and sudden flow, if they could not be taken up in time, they are placed against iron pins inserted in the granite capping, and so regulated in size (by experiments made to that effect) that they must give way under the pressure when the level of the water attains the high-water mark.

As, however, there are obvious objections to this mode of proceeding, the flash-boards have been so arranged, in reference to the pins which support them, that when acted upon by a hydraulic ram, worked from the gate-house and built in its masonry, they are liberated in succession, length after length, at as long intervals of time as may be found necessary, and can be picked up in the river below. They are plain 3-inch planks, uniform in size and interchangeable.

The elevation of the crest of the dam above tide marsh level is 157.54 feet; the elevation of the top of the flash-boards, 159.29.

Numerous headers have been used for the face granite-work, to bond it thoroughly with the backing of rubble masonry; the capping-stones of the overflow and wing walls are held together by dowels placed horizontally; many iron dowels are also used in the gate-chamber to hold its various courses together wherever the stones are most exposed to the pressure, or to the shock, of the water. The gate-chamber (Plates 14 and 15) contains: —

First. The head of the conduit which leads to Farm Pond, with 4 iron gates, 4 ft. × 4½ ft.,[1] to control the flow of the water from reservoir No. 1 into it.

Second. The lower end of the 48-inch pipe connected with the 2 upper dams, also 2 gates, 4 ft. × 4 ft.,[1] to turn the flow from the pipe either into the conduit or into the Sudbury River below.

Third. Three flood-gates, 5 ft. × 6 ft.[1]

Fourth. A floating gauge, indicating the height of water in the reservoir.

Fifth. A gauging apparatus, to measure 1,500,000 gallons, to be let run into the river. (Plates 17 and 18.)

Sixth. A hydraulic ram for the working of the flash-boards.

A house, granite-faced outside and brick-faced inside, is built over the gate-chamber.

Between the dam and Winter-street bridge the river bank on one side, and the conduit embankment on the other, are supported by a wall laid in cement mortar, with a wide foundation of stone laid dry, extending 4 feet below the bed of the stream. On the bottom of the channel, below the apron adjacent to the flood-gates, a heavy paving of rough stones has been laid, which extends some distance below the bridge. The span of the latter is small at that place, and, although its capacity has been very much enlarged by the city, the tendency of the flow through it is to excavate the river bottom below. In the spring of 1878 such an excavation was formed to a depth of some 7 feet below the bed of the river; the depression was subsequently filled with coarse gravel, and the upper 3 feet were filled with heavy stones. In view of the action of the water, the walls supporting the conduit embankment near the bridge have a deep foundation. A similar depression in the bed of the stream, more than 10 feet in depth, exists below the 3 arches of the bridge, which have not been altered by the city. Before the city had commenced any work of construction this bridge was severely taxed by the action of the freshet of March, 1876, which partially carried away the floor of one of its spans and caused some settlement in the masonry.

In view of the fact that sewers may be required in the course of time to carry away

[1] These dimensions are those of the opening in the stone-work; the actual opening, owing to the iron frame which fits the stone, is 2 inches less vertically and horizontally.

the objectionable drainage from the margin of the reservoirs, a 16-inch cast-iron pipe has been laid through the embankment of the dam on each side of the river, and built through its centre wall. (Plate 13.)

Both pipes are built in the centre wall, and are provided with several "cut-water" walls; they are capped at the upper end and terminate into a brick cesspool; the cesspool on the south side receives the drainage of a small piece of land belonging to the city on the east side of Winter street; it empties into the river by means of a pipe which passes over the conduit and is embedded in the upper part of the arch. (For details of the construction of Dam No. 1, see Plates 13 to 18, inclusive.)

The 48-inch pipe which connects the 3 dams together is laid entirely in Reservoir No. 1. One branch starts from Dam No. 2 in the masonry of which it is built, and follows the margin of Reservoir No. 1 to a point 1,362 feet above Dam No. 1, where it meets the other branch. The latter starts from the gate-chamber of Dam No. 3, follows on the same side the edge of Reservoir No. 1, crosses the bed of Stoney Brook in siphon, then rises to a point 135 feet north of Salem street, where it is connected with a 16-inch vertical air-pipe, 17½ feet high above the ground, protected by a brick shaft. Thence the pipe takes a downward course towards the river, and, before entering the reservoir again, is provided with a man-hole; it passes the bed of the river in siphon and meets the other branch.

From the point of meeting of the two branches the pipe is laid towards Dam No. 1, which it enters after a short compound curve, which has been designed to leave the bed of the river unobstructed in front of the gates.

The grade of the pipe is such that the air enclosed in it can rise freely towards either of the dams or towards the air-pipe.

The 3 dams and the 48-inch pipe having been built and laid each by a different contractor, the ends of the pipe, where they are connected with the gate-houses, were laid by the city by day labor.

RESERVOIR NO. 2.

This reservoir, a long and comparatively narrow sheet of water, extends from Dam No. 2, which limits the southerly arm of Reservoir No. 1, in a south-westerly direction, towards Ashland, and terminates at the dam of (formerly) the Washington Emery Mills Manufacturing Co. in that town. For a part of its length it follows the track of the Boston & Albany Railroad, which crosses it at the southern end.

In the lower part the flowage covers farming land connected with estates which, in several instances, were cut in two by the water without means of access to the portions left on the west side; the estate of Mrs. Harriette F. Nevins among them was peculiarly situated, owing to the existence of a long run of low land, wherein the flowage of the reservoir extended as far as Park's Corner, around the back part of the house, and through the yards where several buildings, stables, etc., stood at a level inferior to water-mark. In order to avoid the objectionable feature of a large area of reservoir within the heart of the estate it was decided to fill a portion of the land which was to be flowed, and to raise the buildings situated on it. This operation was accepted by the owner as a part compensation for her claim for damages; and by mutual consent, at her request, the portion of the reservoir behind the house was considerably enlarged and deepened, the material coming out of it being used for forming the greater part of the filling.

Further up on the reservoir the estates flowed were of lesser value.

Two water privileges were destroyed, and 3 manufacturing establishments had to be removed, as follows, viz.: —

First. A grist-mill of some magnitude, belonging to the Cutler Brothers, with

RESERVOIR NO. 1.

Capacity and Storage in million gallons.

Determined from contours of the flow-lines as actually located, and from the preliminary cross-sections taken in 1872.

Crest of dam . . . . . 157.54.

Top of first flash-boards . . . 158.41.

Top of second flash-boards . . . 159.29.

Grades above Tide Mean Water Level.	Capacity.	Storage.	Capacity.	Storage.	Capacity.	Storage.	Capacity.	Storage.	Capacity.	Storage.	Capacity.	Storage.	Capacity.	Storage.	Capacity.	Storage.	Capacity.	Storage.	Capacity.	Storage.	Capacity.	Storage.	Capacity.	Storage.
	0		.10		.20		.30		.40		.50		.60		.70		.70		.80		.90			
152	37.6	1.9	39.5	1.9	41.4	2.0	43.4	2.1	45.5	2.1	47.6	2.2	49.8	2.2	52.0	2.3	52.0	2.3	54.3	2.3	56.6	2.3		
153	58.9	2.4	61.3	2.4	63.7	2.4	66.1	2.5	68.6	2.6	71.2	2.6	73.8	2.7	76.5	2.8	76.5	2.8	79.3	2.8	82.1	2.9		
154	85.0	2.9	87.9	2.9	90.8	2.9	93.7	3.0	96.7	3.0	99.7	3.0	102.7	3.1	105.8	3.1	105.8	3.1	108.9	3.2	112.1	3.2		
155	115.3	3.2	118.5	3.2	121.7	3.3	125.0	3.4	128.4	3.5	131.9	3.5	135.4	3.6	138.9	3.5	138.9	3.5	142.4	3.5	145.9	3.6		
156	149.5	3.6	153.1	3.6	156.7	3.7	160.4	3.7	164.1	3.8	167.9	3.8	171.7	3.9	175.6	3.9	175.6	3.9	179.5	3.9	183.4	4.0		
157	187.4	4.0	191.4	4.0	195.4	4.1	199.5	4.1	203.6	4.1	207.7	4.2	211.9	4.2	216.1	4.3	216.1	4.3	220.4	4.3	224.7	4.3		
158	229.0	4.4	233.4	4.4	237.8	4.5	242.3	4.5	246.8	4.5	251.3	4.6	255.9	4.6	260.5	4.6	260.5	4.6	265.1	4.7	269.8	4.7		
159	274.5	4.8	279.3	4.8	284.1	4.8	288.9	4.8	293.7	4.9	298.6	4.9	303.5	5.0	308.5	5.0	308.5	5.0	313.5	5.1	318.6	5.2		
160	323.8	5.2	329.0	5.2	334.2	5.3	339.4	5.3	344.7	5.3	350.0	5.3	355.3	5.4	360.7	5.4	360.7	5.4	366.1	5.4	371.5	5.4		
161	376.9	...	....	...	....	...	....	...	....	...	....	...	....	...	....	...	....	...	....	...	....	...		

OK FILE JWC

INSPECTION REPORT - DAMS AND RESERVOIRS

(1.) Location: ~~City~~/Town FRAMINGHAM Dam No. 4-9-100-3

Name of Dam SUDBURY RIV. RESERV. #1 Inspected by A.Z. PIZAN + F.H. PARE

Date of Inspection 7-25-'73

(2) Owners: por: Assessors ✓, Prev. Inspection ____

Reg. of Deeds ____ Pers. Contact ____

	Name	St. & No.	~~City~~/Town	State	Tel. No.
1.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	M.D.C.	20 SOMERSET ST.	BOSTON	MASS. 02114	727-5215
2.					
3.					

(3) Caretaker: (if any) e.g. superintendent, plant manager, appointed by absentee owner, appointed by multi owners.

Name	St. & No.	City/Town	State	Tel. No
SAME				

(4) No. of Pictures taken NONE

(5) Degree of Hazard: (if dam should fail completely)*

1. Minor ____ 2. Moderate ____

3. Severe ✓ 4. Disastrous ____

*This rating may change as land use changes (future development)

(6) Outlet Control: Automatic ____ Manual ✓

Operative ✓ yes: ____ no.

Comments: SLUICE GATES MAINTAIN WATER FLOW THROUGH SPILLWAY. WATER DOES NOT FLOW OVER DAM. SLUICE GATES ARE IN GATE HOUSE. (5'x5')

(7) Upstream Face of Dam: Condition:

1. Good ✓ 2. Minor Repairs ____

3. Major Repairs ____ 4. Urgent Repairs ____

Comments: ____

DAM NO. 4-9-100-3

(8) Downstream Face of Dam: Condition: 1. Good ✓ 2 Minor Repairs____

3. Major Repairs____ Urgent Repairs__

Comments:_____

(9) Emergency Spillway: Condition: 1. Good ✓ 2. Minor Repairs____

3. Major Repairs____ 4. Urgent Repairs____

Comments:_____

(10) Water level @ time of inspection ____ ft, above____ below 10'

top of dam ✓ Principal spillway_____

other_____

(11) Summary of Deficiencies Noted:

Growth (Trees and Brush) on Embankment_____

Animal Burrows and Washouts_____

Damage to slopes or top of dam_____

Cracked or Damaged Masonry_____

Increase of Seepage_____

Evidence of Piping_____

Erosion_____

[illegible]

Accumulation of debris around [illegible]

[illegible] or blocked spillway_____

NO DEFICIENCIES NOTED.

DAM NO. 4-9-100-3

(12.) Remarks & Recommendations: (Fully Explain)

DAM IS IN EXCELLENT CONDITION.

(13.) Overall Condition:

1. Safe ✓
2. Minor repairs needed _____
3. Conditionally safe, major repairs needed _____
4. Unsafe _____.
5. Reservoir impounding no longer exists (explain)

Recommend removal from inspection list _____

DESCRIPTION OF DAM
DISTRICT #4

Submitted by FRANCIS H. PARÉ & ADAM Z. PIZAN Dam No. 4-9-100-3
Date 7/25-73 City/Town FRAMINGHAM 01701
Name of Dam RESERVOIR #1

1. Location: Topo Sheet No. 26 C
Provide 8½" x 11" in clear copy of topo map with location of Dam clearly indicated.

2. Year built: 1900 Years of subsequent repairs UNKNOWN

3. Purpose of Dam: Water Supply ✓. Recreational ____
Irrigation ____. Other ____

4. Drainage Area: 2 SQ. MI. 080 ACRES.

5. Normal Ponding Area, 154 acres; Ave. Depth 15'
Impoundment: 770 MIL. gals; 2310 acre ft.

6. No. and type of dwellings located adjacent to pond or reservoir ____
i.e., summer homes etc. 1 GATE BLD. ADJACENT TO DAM, 2 PERMANENT HOMES WINTER ST.

7. Dimensions of Dam: Length 168' Max. Height 20'
Slopes: Upstream Face VERT
Downstream Face "
Width across top 8'

8. Classifications of Dam by Materials:
Earth ✓, Conc. Masonary ____, Stone Masonary ✓
Timber ____, Rockfill ____, Other ____

9. A. Design point of [illegible] land usage downstream of dam: 20 % current
80 % ultimate

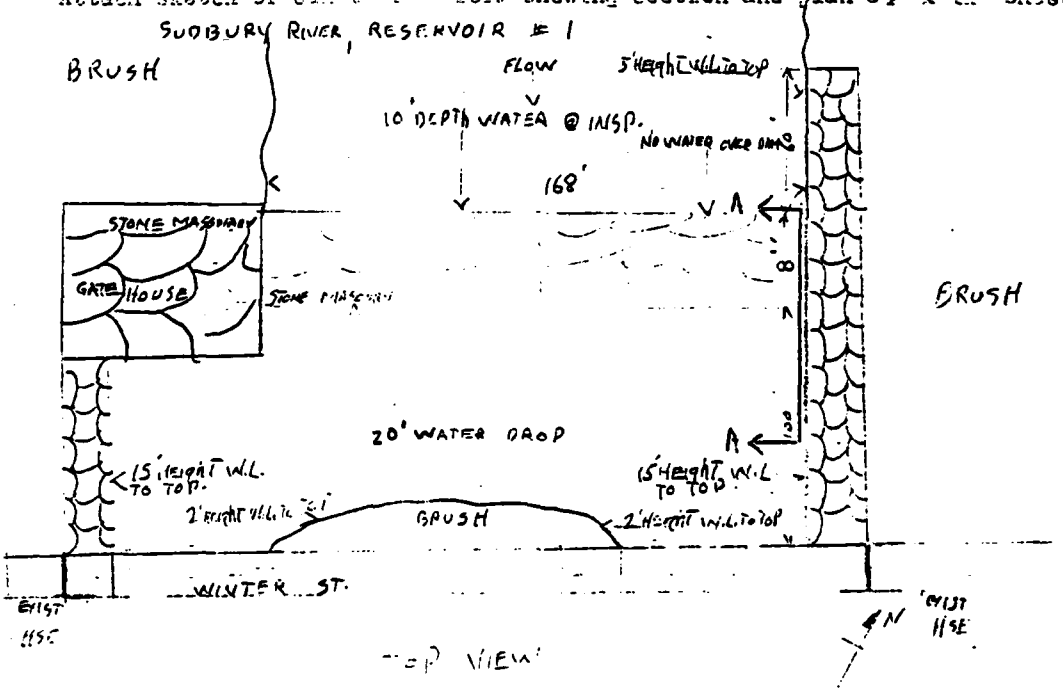
B. Is there a known flood plain downstream of dam? Which would accommodate the runoff in the event of a complete dam failure
No ✓

DAM NO. 4-9-100-3

10. Risk to life and property in event of complete failure.

No. of people EST. 300 3 PERSONS PER HOME
No. of homes " 100
No. of businesses NONE
No. of industries " Type
No. of utilities " Type
Railroads "
Other dams "
Other

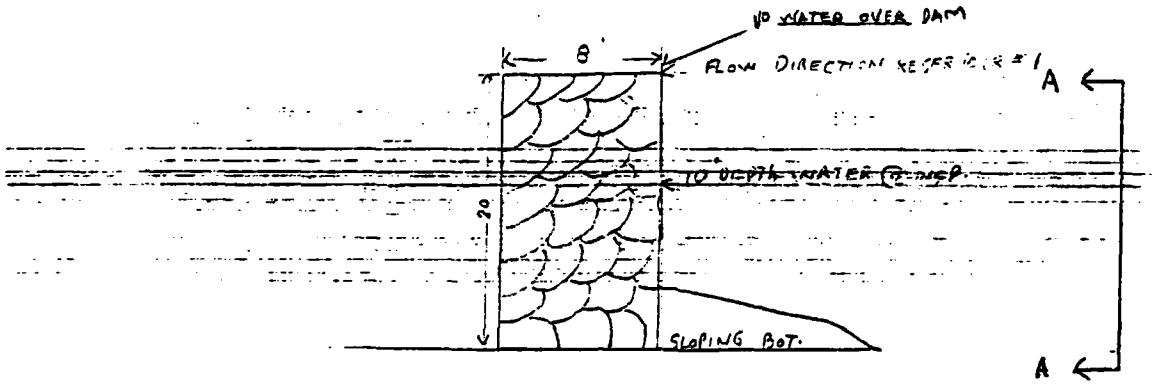
11. Attach sketch of dam [illegible] form showing section and plan 8½" x 11" Sheet.



TOP VIEW

SKETCH [illegible] SCALE

4-9-100-3



X SECTION AA

SKETCH NOT TO SCALE

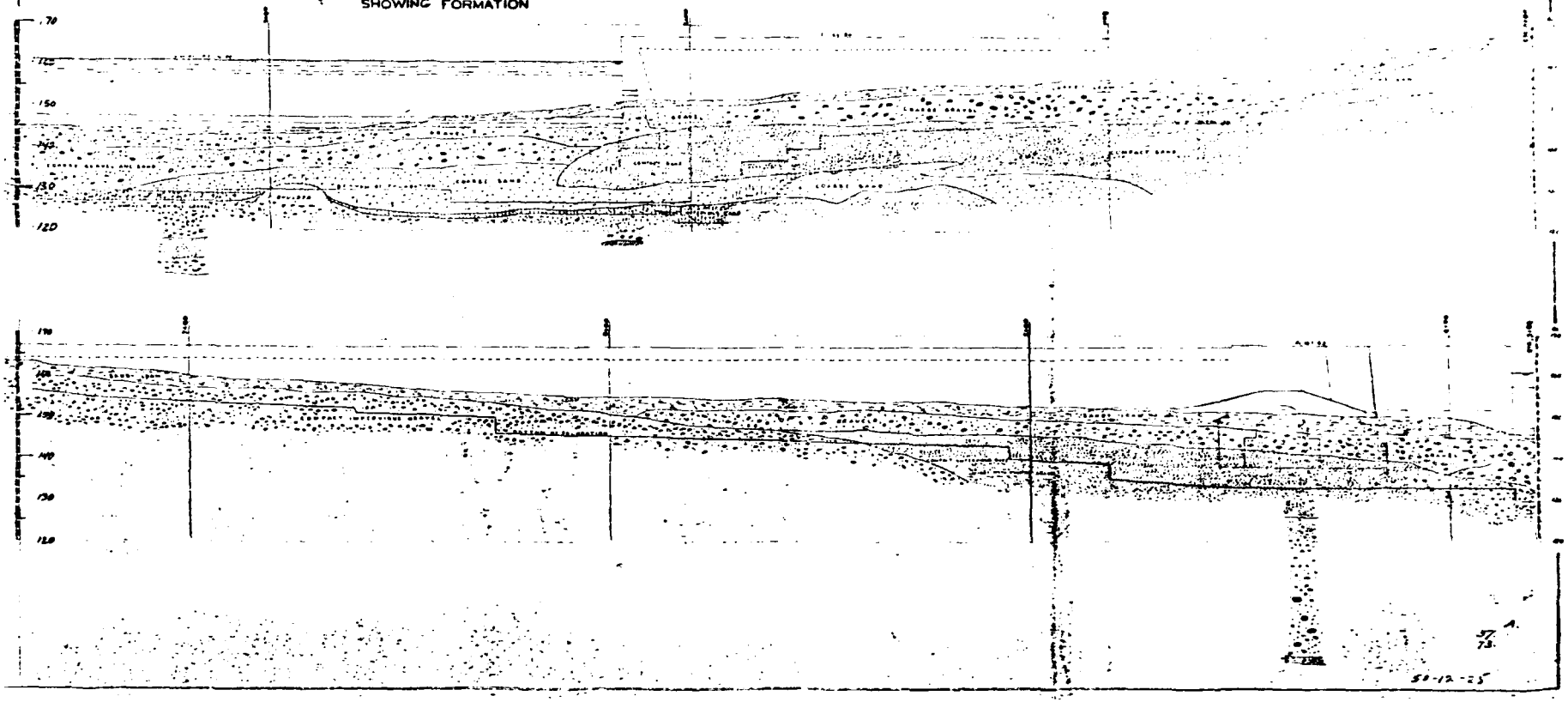
BOSTON WATER WORKS

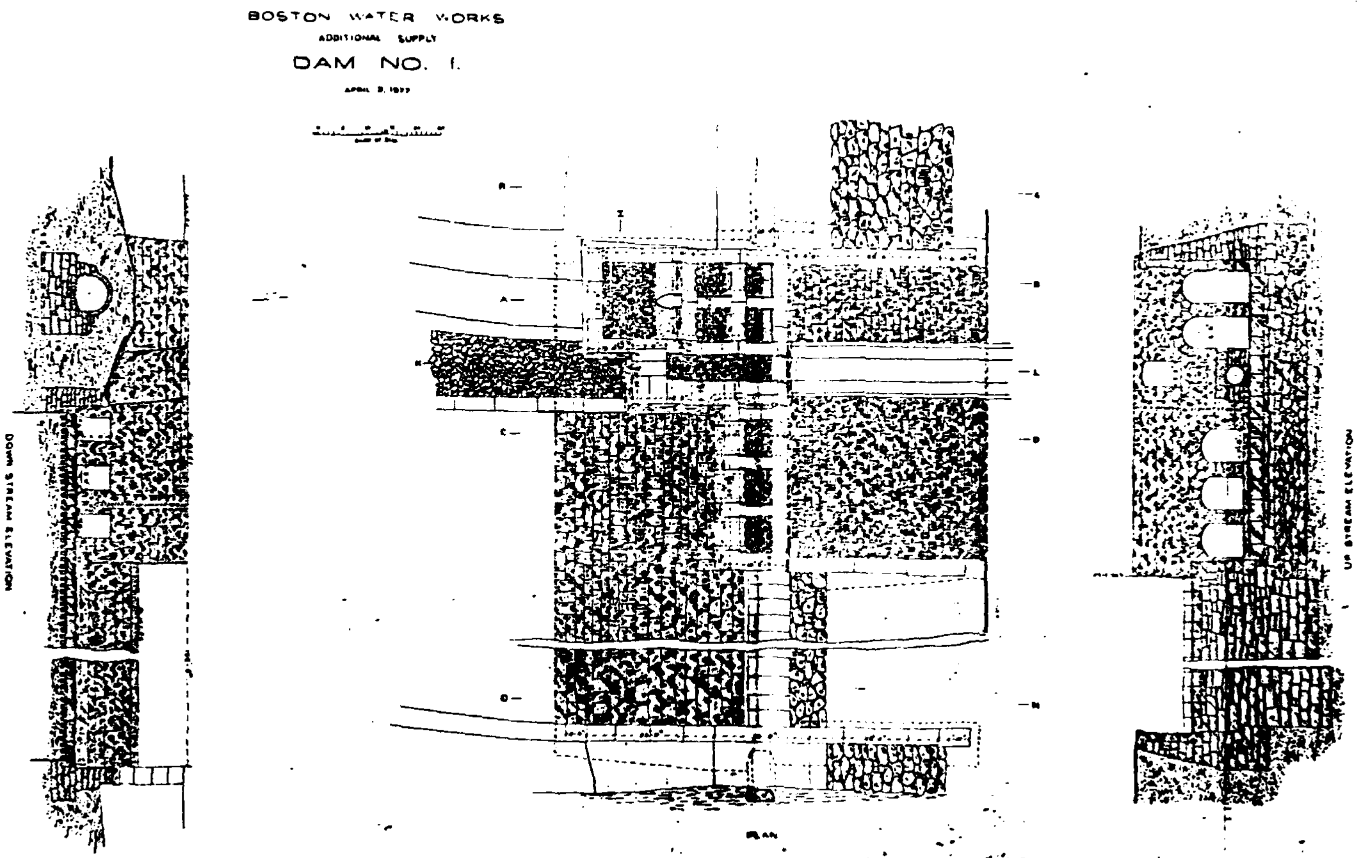
ADDITIONAL SUPPLY

DAM NO. 1.

LONGITUDINAL SECTION

SHOWING FORMATION



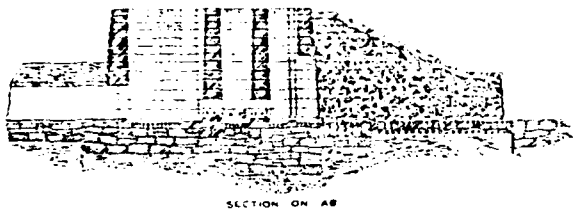


BOSTON WATER WORKS

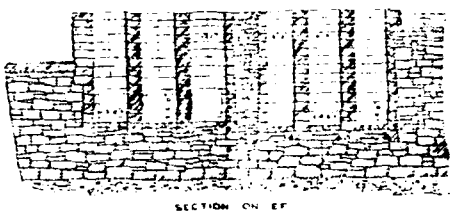
ADDITIONAL SUPPLY

DAM NO. 1.

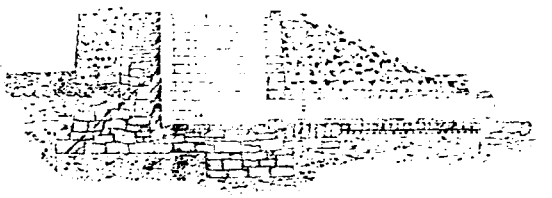
APRIL 1877



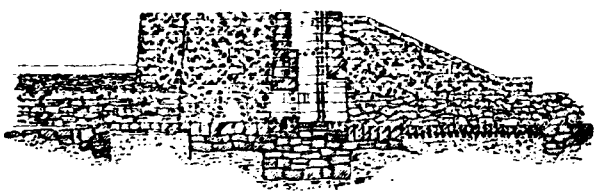
SECTION ON AB



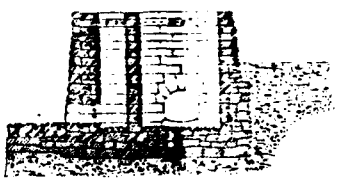
SECTION ON EF



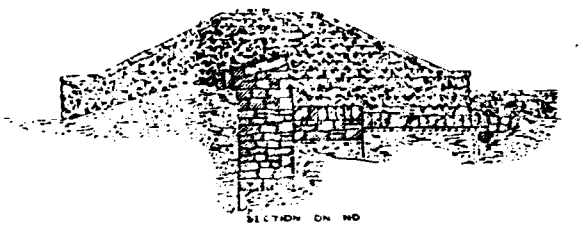
SECTION ON KL



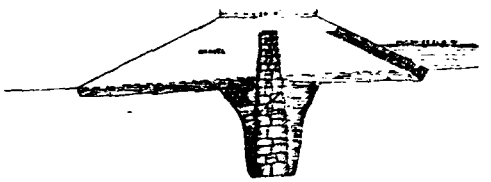
SECTION ON CD



SECTION ON GH



SECTION ON MO



SECTION ON RS

37
73

4.

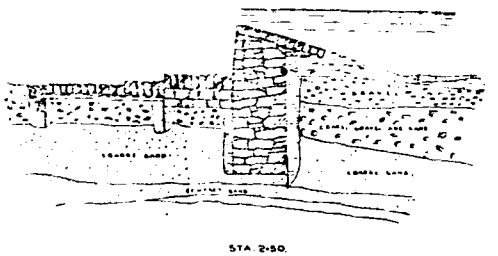
1877

BOSTON WATER WORKS

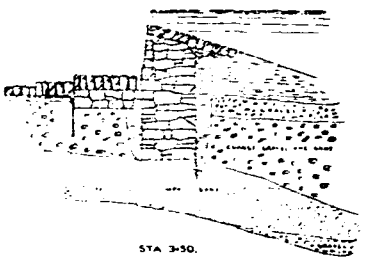
ADDITIONAL SUPPLY

DAM NO. 1.

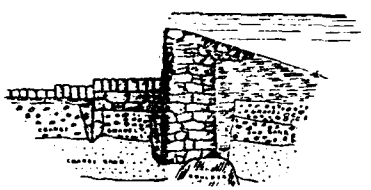
CROSS SECTIONS



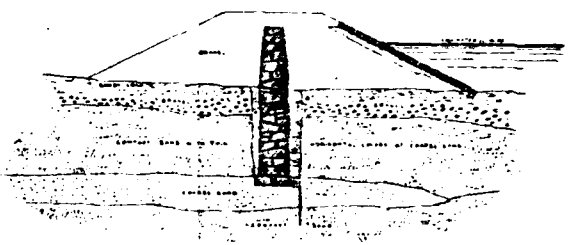
STA. 2+50.



STA. 3+50.



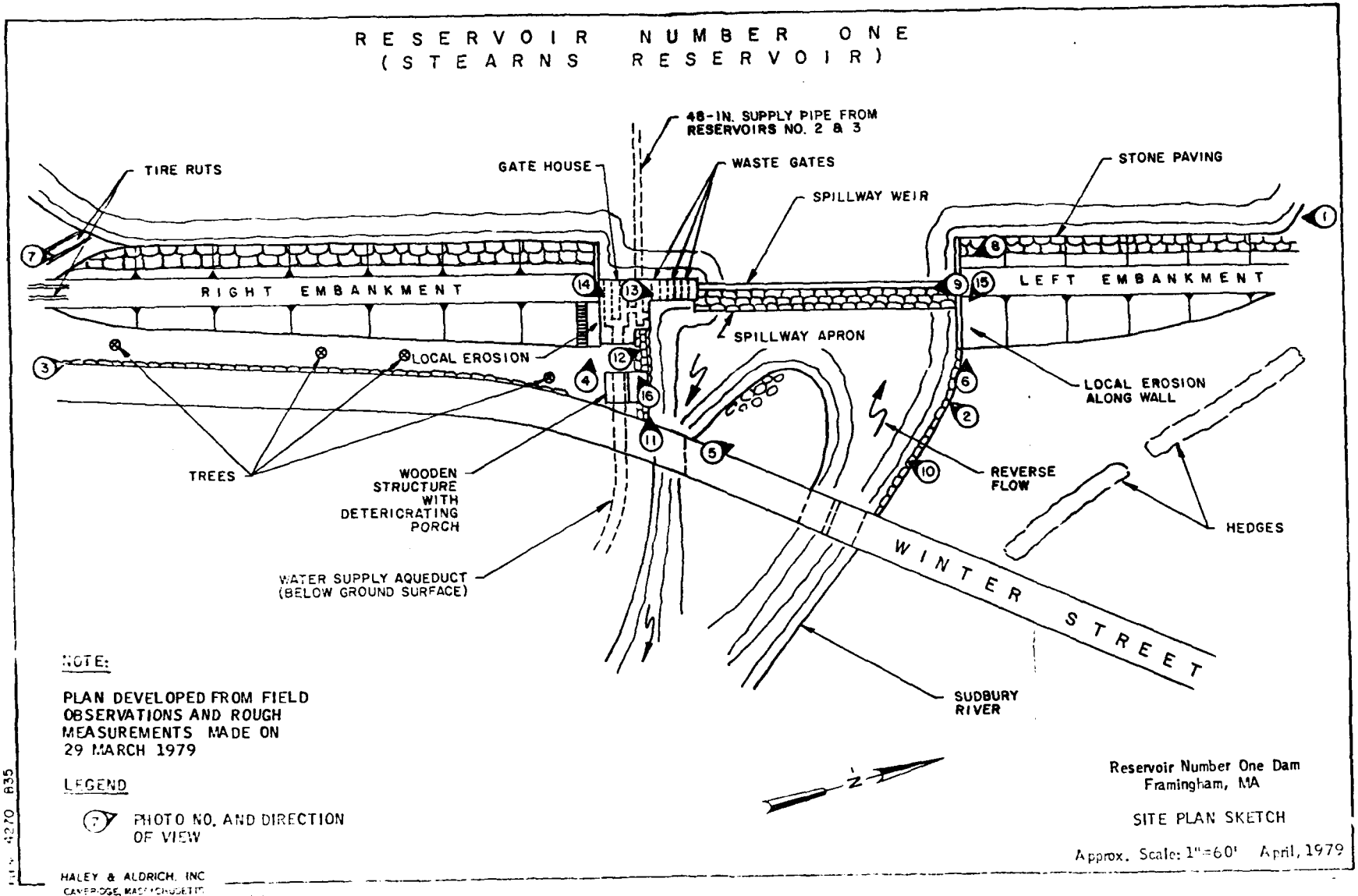
STA. 2+90.



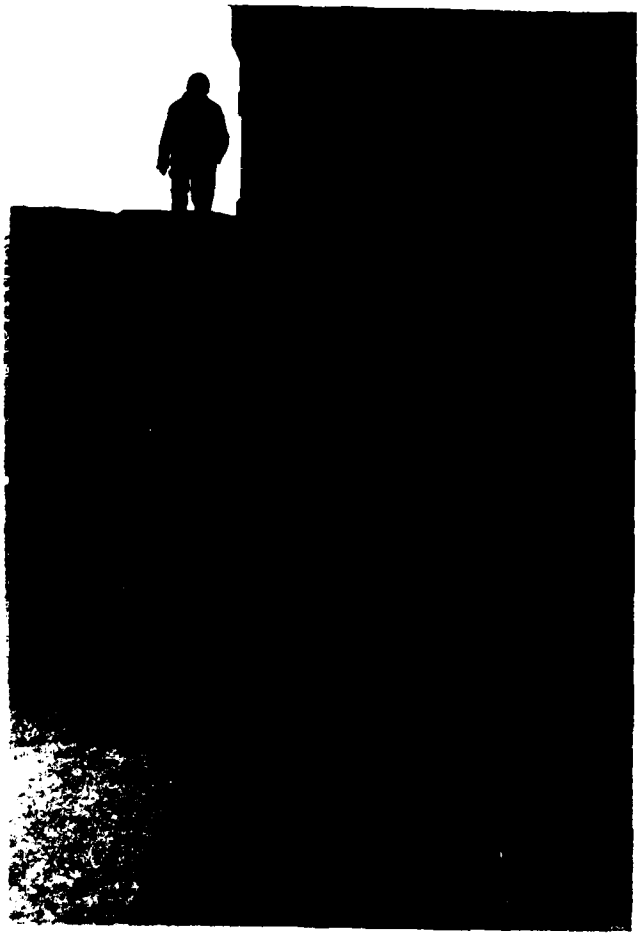
STA. 4+97.

16

APPENDIX C - PHOTOGRAPHS


RESERVOIR NUMBER ONE
(STEARNS RESERVOIR)
48-IN. SUPPLY PIPE FROM RESERVOIRS NO. 2 & 3
TIRE RUTS
GATE HOUSE
WASTE GATES
SPILLWAY WEIR
STONE PAVING
RIGHT EMBANKMENT
LEFT EMBANKMENT
SPILLWAY APRON
LOCAL EROSION
LOCAL EROSION ALONG WALL
TREES
WOODEN STRUCTURE WITH DETERIORATING PORCH
REVERSE FLOW
HEDGES
WATER SUPPLY AQUEDUCT (BELOW GROUND SURFACE)
WINTER STREET
SUDBURY RIVER
NOTE:
PLAN DEVELOPED FROM FIELD OBSERVATIONS AND ROUGH MEASUREMENTS MADE ON 29 MARCH 1979
LEGEND
PHOTO NO. AND DIRECTION OF VIEW
Reservoir Number One Dam
Framingham, MA
SITE PLAN SKETCH
Approx. Scale: 1"=60' April, 1979
HALEY & ALDRICH, INC
CAMBRIDGE, MASSACHUSETTS

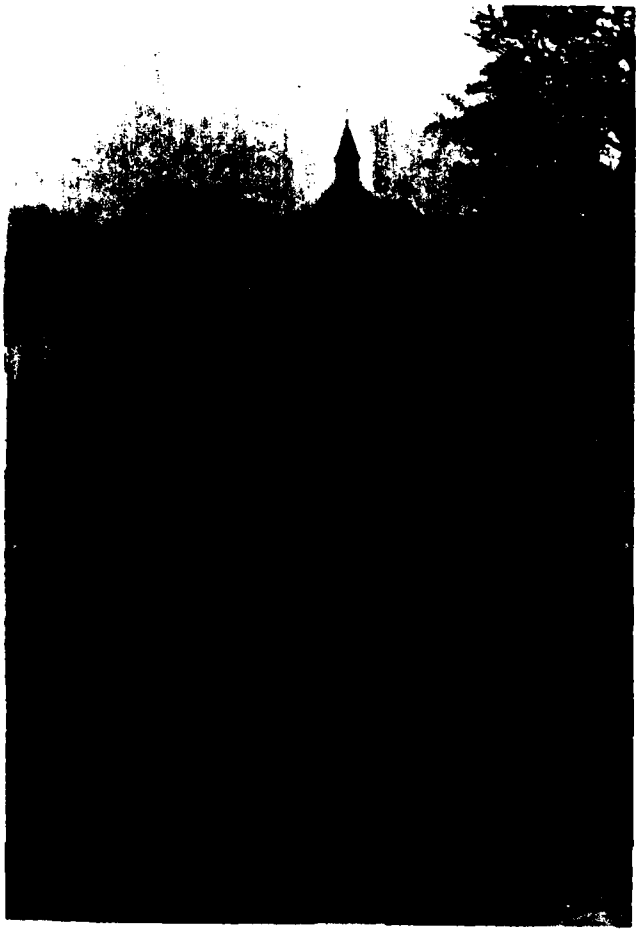
3. Crest and downstream slope of right embankment



4. Erosion of downstream slope adjacent to gate house

5. Downstream slope of left embankment

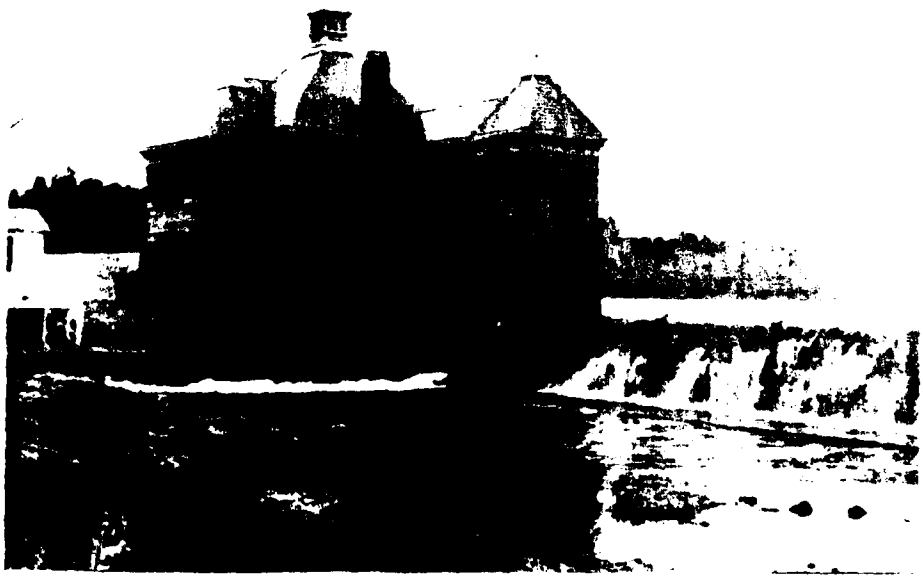
6. Erosion of downstream slope adjacent to left spillway training wall



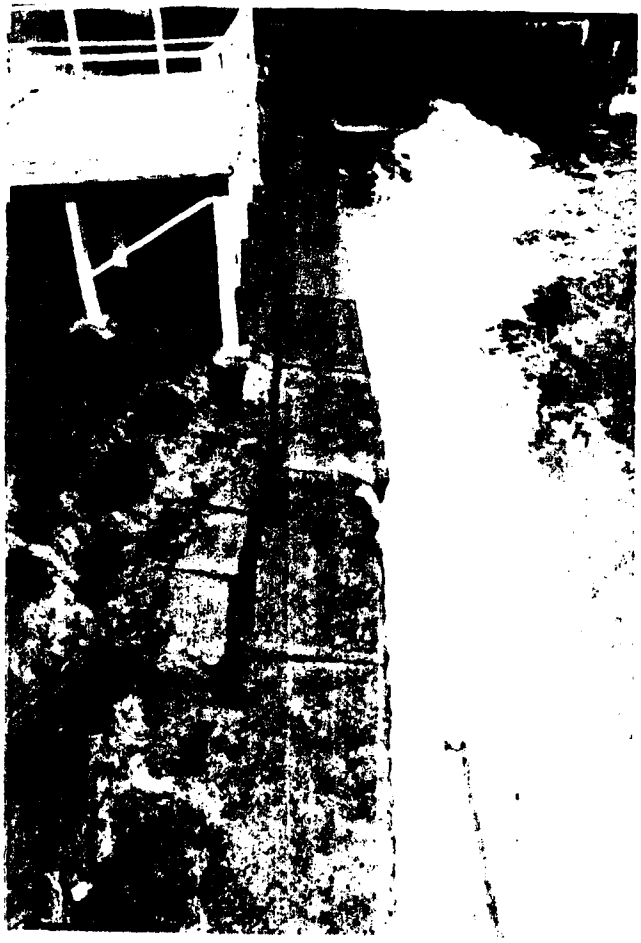
7. Upstream side of right embankment. Note the ruts on crest near right abutment

8. Stone paving and slight erosion at right abutment of left embankment

9. Spillway weir and apron



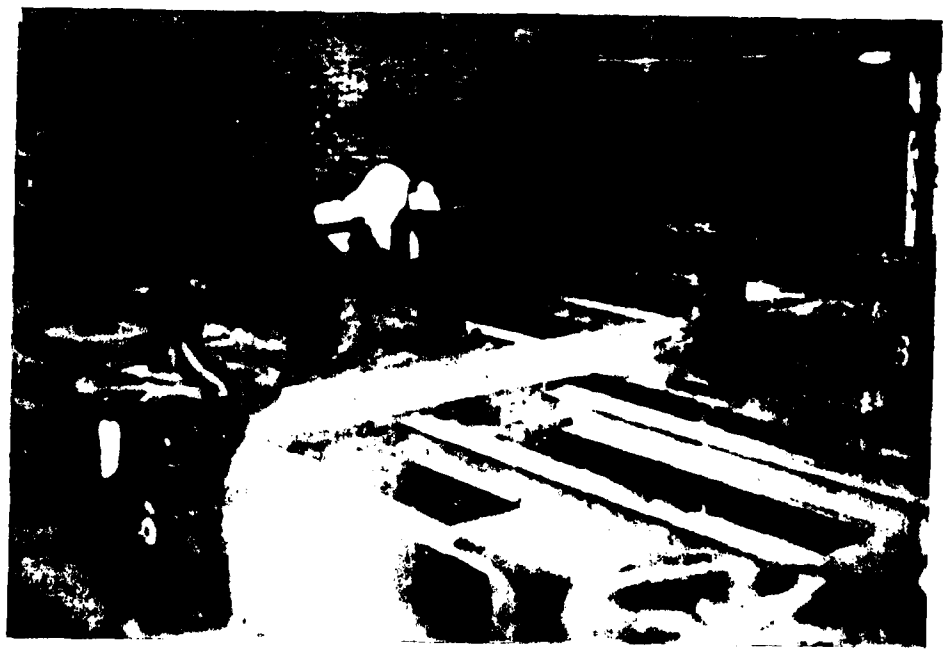
10. Gate house and waste gate outlet ports



11. Tilted right discharge channel wall

12. Stone riprap has settled above right discharge channel wall

13. Double-stemmed controls for three waste gates, taken inside gate house

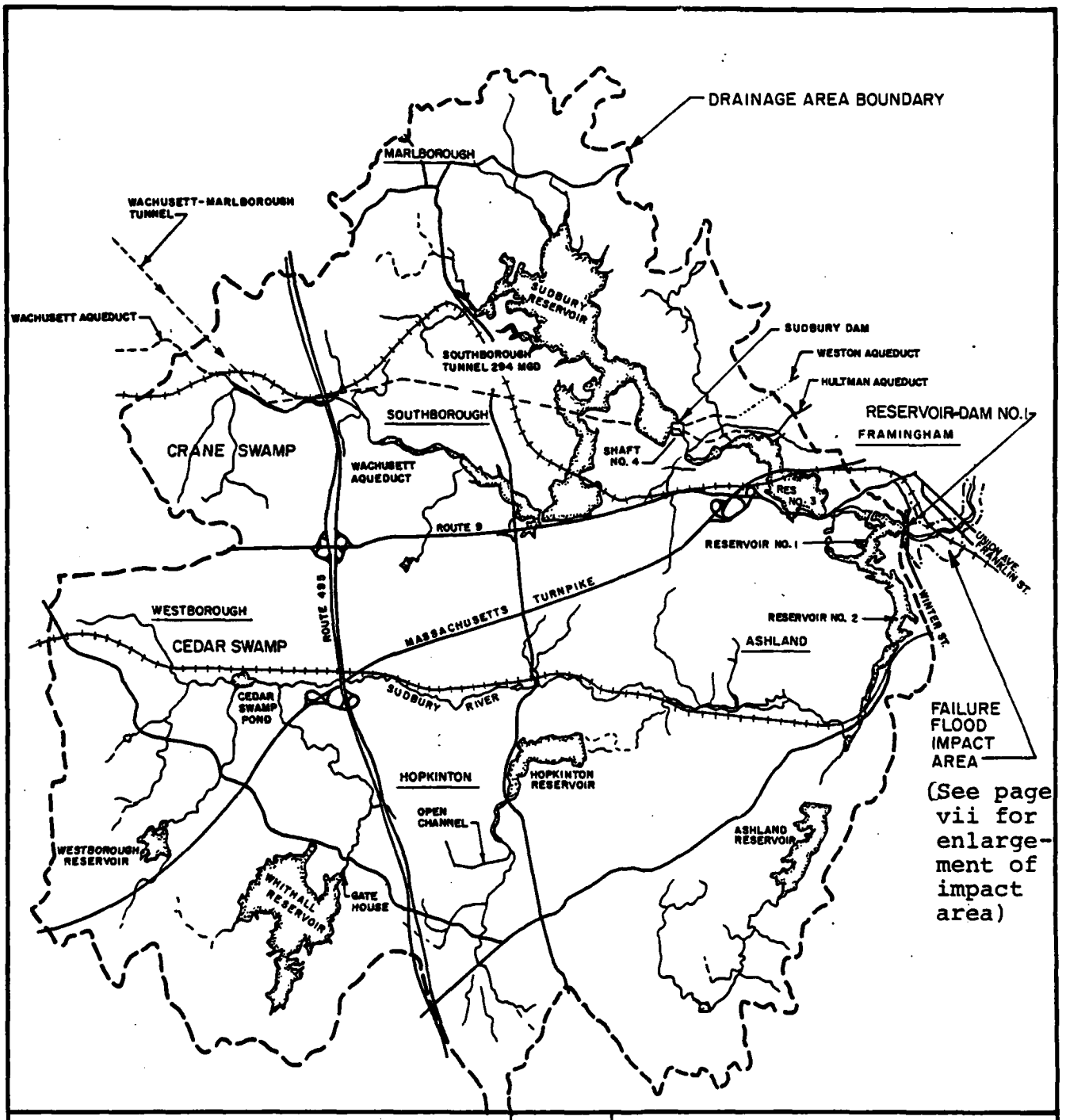


14. Gate controls and floor openings inside gate house

15. Spillway discharge channel and Winter Street bridge openings

16. Foundation for collapsing porch of wood structure downstream of gate house

APPENDIX D - HYDROLOGIC AND HYDRAULIC COMPUTATIONS



(See page vii for enlargement of impact area)

CAMP DRESSER & McKEE Inc.
Consulting Engineers
Boston, Mass.

RESERVOIR NO.1
DRAINAGE & FLOOD IMPACT AREAS
SCALE : 1 : 100,000

CAMP DRESSER & McKEE INC. CLIENT H & A JOB NO 561-9-Rt-6 PAGE 1
PROJECT COE Dam Inspection DATE CHECKED 5/9/79 DATE 5/7/79
DETAIL RESERVOIR NO. 1 CHECKED BY RHS COMPUTED BY AHC

Size Classification

Dam Height : Els. 171.4 - 149.4 = 22 -Ft < 40 -Ft

Storage Volume : 3,075 acre-ft @ EL. 171.4 > 1000 ac-ft

SIZE : INTERMEDIATE

Hazard Potential

In the event of a dam failure, a large residential area including a school along the left bank and several industrial and commercial buildings and a school on the right bank of the downstream channel are expected to be flooded. The hazard potential is considered high because of a potential for loss of lives and excessive residential, institutional, industrial and commercial property damages.

Test Flood Development

Size : Intermediate ; Hazard Potential : high

Q_p = PMF

Watershed Area : 74.3 sqmi = 47,552 acres

Peak Flow Rate: 270 cfs/sqmi as shown in the COE guidelines, for the Sudbury River basin at a point where the drainage area is 86 sqmi.

PMF = 74.3 x 270 ≅ 20,000 cfs, then :

Test Flood Inflow = 20,000 cfs.

CAMP DRESSER & McKEE INC. CLIENT H+A JOB NO 561-9-PT PAGE 2
PROJECT COE Dam Inspection DATE CHECKED 5/9/79 DATE 5/8/79
DETAIL RESERVOIR NO. 1 CHECKED BY RHS COMPUTED BY AHL

Surcharge - Storage Routing

Q_{P_1} = 20,000 cfs (PMF → Max. Runoff = 19.0")

WSE in Pond : 175.7 (see Stage-Discharge Curve in page D-4)

Reservoir Volume : 5,300 ac-ft (See Area-Volume curve, Page D-5)

Normal Reservoir Volume : 600 ac-ft @ El ≈ 162.0

$STOR\ 1 = \frac{(5,300-600)12}{47,552} = 1.19"$

$Q_{P_2} = 20,000\left(1 - \frac{1.19}{19}\right) = 18,750$ cfs WSE in Pond = 175.4
V = 5,150 ac-ft

$STOR\ 2 = \frac{(5,150-600)12}{47,552} = 1.15"$ $STOR_{AV} = 1.17"$

$Q_{P_3} = 20,000\left(1 - \frac{1.17}{19}\right) = 18,770$ cfs WSE in Pond = 175.4

Therefore :

Test Flood Outflow ≅ 18,800 cfs @ El. 175.4

Tail Water

Q = 18,800 cfs → WSE @ downstream of the dam : 171.5
(See Stage-Discharge curve, page D-6)

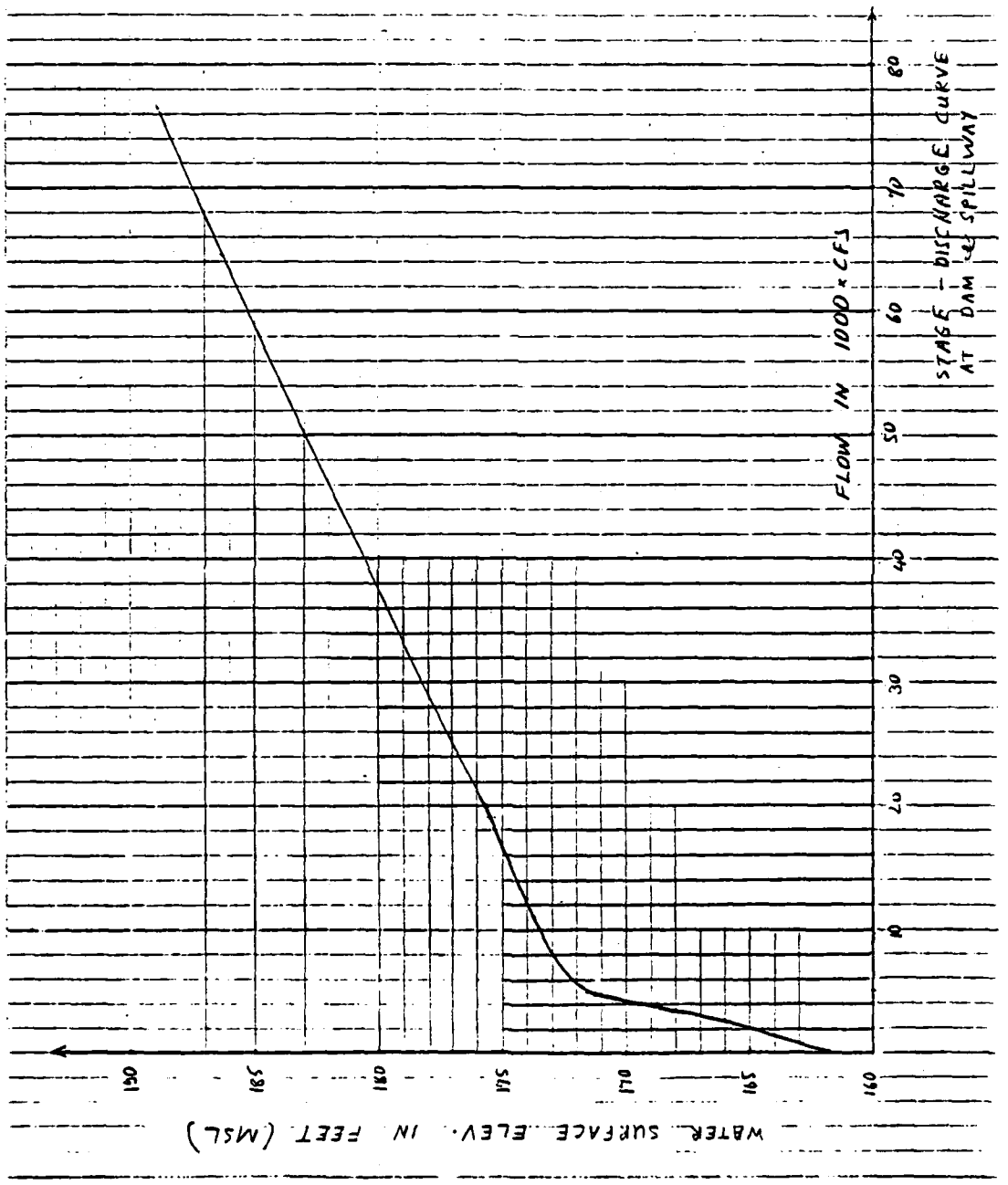
The spillway crest would be submerged by (171.5 - 161.9) = 9.6 Ft. feet.

CAMP DRESSER & McKEE INC.

CLIENT: H & A
PROJECT: Dam Inspection
DETAIL: Reservoir No. 1

JOB NO: 561-9-82-6
DATE CHECKED: 5/9/79
CHECKED BY: RHS

PAGE: 3
DATE: 5/7/79
COMPUTED BY: MHG



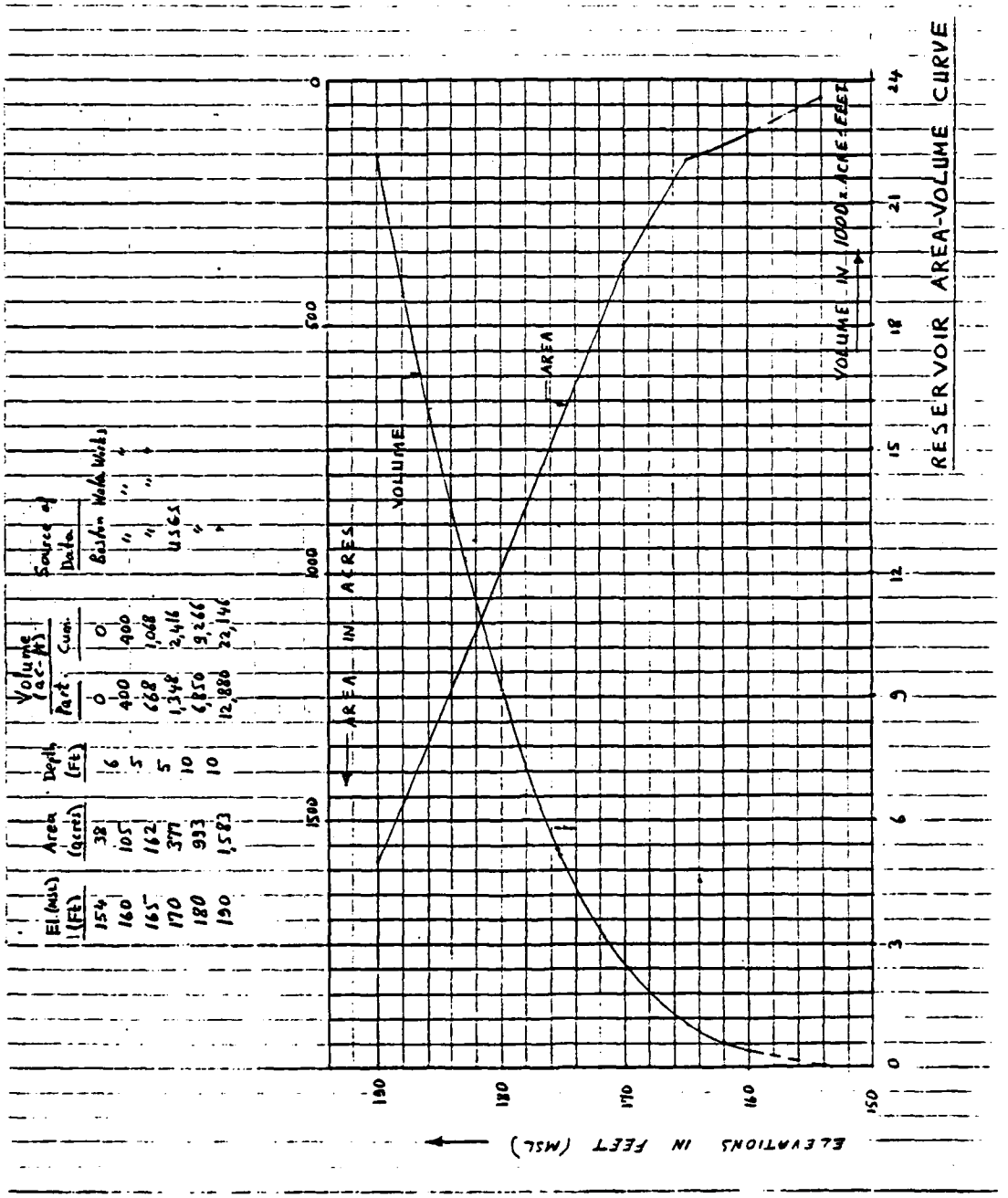
CAMP DRESSER & McKEE INC.

CLIENT H&A
PROJECT COE Dam Inspection
DETAIL RESERVOIR NO. 1

JOB NO 561-9-Rt-6
DATE CHECKED 5/3/79
CHECKED BY AUG

PAGE 4
DATE 4/11/79
COMPUTED BY J.L.M.

El. (MSL) (Ft)	Area (acres)	Depth (Ft)	Volume (ac-ft) Part.	Volume (ac-ft) Cum.	Source of Data
154	38	6	0	0	Basin Mod. Wks
160	105	5	400	400	"
165	152	5	668	1,068	"
170	377	10	1,348	2,416	USGS
180	933	10	6,850	9,266	"
190	1,583	10	12,880	22,146	"

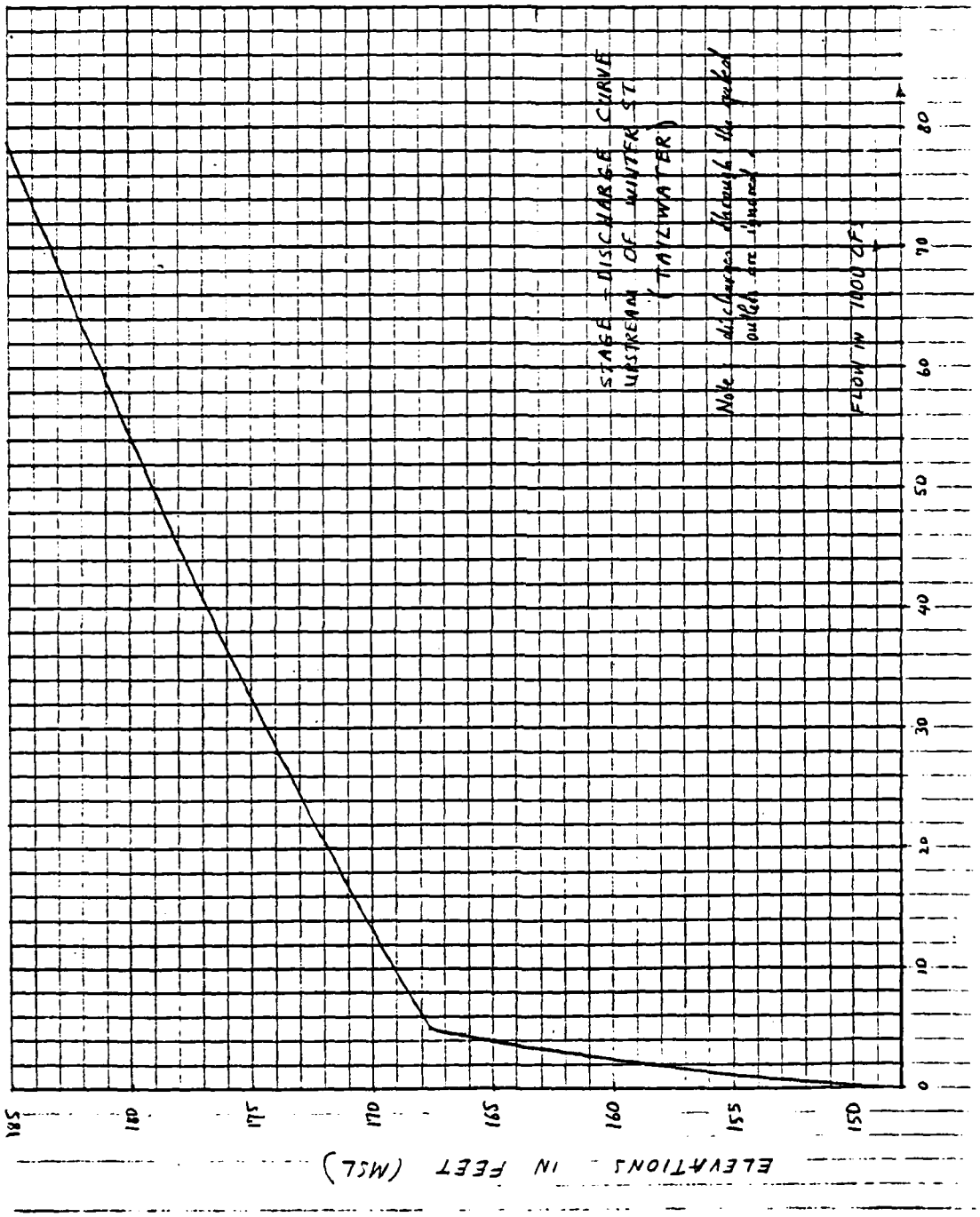


CAMP DRESSER & McKEE INC.

CLIENT H & A
PROJECT Dam Inspection
DETAIL RESERVOIR NO. 1

JOB NO 561-5-PH-6
DATE CHECKED 5/9/79
CHECKED BY RHS

PAGE 5
DATE 5/7/79
COMPUTED BY AHC



Capacity of Existing Spillway

$Q \cong 3.5 \times 168 \times \sqrt{9.5}^{3/2} = 17,217$ cfs. This could be possible if there was no restriction to the flow in the downstream channel. Tailwater el. = 171.1 > 161.9 spillway crest. There is a backflow effect from the downstream channel. Therefore, a capacity of Q = 4,600 cfs at Pond WSE = 171.4 (top of the dam) would be obtained from Stage-Discharge Curve in Page D-4. Tailwater would be at El. 166.3 (See Stage-discharge curve, page D-6).

$C \cong 2.6$ for WSE's < 172.0.

Flow over spillway during test flood Pool El. = 175.4

Tail water el. = 171.5

$\Delta H = 3.9'$ $\quad Q \cong 3.5 \times 168 \times \sqrt{3.9}^{3/2} = 4,530$ cfs.

Conclusion. The existing spillway capacity is about 25 percent of the estimated test flood outflow. This is mainly because of the capacity restriction in the downstream channel. If the downstream channel capacity were adequate the spillway capacity would be about 92 percent of the test flood outflow. Increasing the dam height without any improvements to the downstream channel would not help to increase the spillway capacity.

CAMP DRESSER & McKEE INC. CLIENT H & A JOB NO 561-9-RT-6 PAGE 7
PROJECT COE Dam Inspection DATE CHECKED 5/9/79 DATE 5/8/1979
DETAIL RESERVOIR NO. 1 CHECKED BY RHS COMPUTED BY AHE

Dam Failure Analysis

Failure Flood Flow: $Q_{p_1} = \frac{8}{27} W_b \sqrt{g}\, y_o^{3/2}$

$y_o = 171.4 - 149.4 = 22.0$ Ft.

$W_b = 0.4 \times 488 = 195'$ Dam length of 488 Feet at the mid-height was determined from a longitudinal section prepared by Boston Water Works in 1877.

$Q_{p_1} = \frac{8}{27} \times 195 \times 5.67 \times 22^{1.5} = 33,800$ cfs. (if there was no restriction in the downstream channel)

Storage Volume @ El. 171.4 (top of the dam) = 3,000 ac-ft

Maximum discharge at the downstream channel at el. 171.4, (which is assumed to be the elevation at time of failure) from page D-6 : 18,200 cfs < 33,800 cfs.

The failure flow, then = 18,200 cfs (all the bridges over the downstream channel are assumed to remain intact)

Reach 1: Dam to Railroad Bridge: $A_{dam} = 4,400$ ft^2 $A_{winter\ st.\ upst.} = 3,300$ ft^2

$L_a = 120'$ $V_{1-a} = 11$ ac-ft WSE @ Winter st. = 171.4

$A_{winter\ downst} = 4,200$ ft^2 ÷ RR Bridge upstream $A = 9,300$ ft^2 $V_{1-b} = 345$ ac-ft

$L_b = 2,230'$

$V_1 = 11 + 345 = 356$ ac-ft.

Q_{p_2} (Trial) $= 18,200 \left(1 - \frac{356}{3,000}\right) \cong 16,000$ cfs

$V_2 = 340$ ac-ft $V_{av} = 348$ ac-ft.

$Q_{p_2} = 18,200 \left(1 - \frac{348}{3,000}\right) \cong 16,100$ cfs. @ WSE = 168.7 upstream of the Railroad bridge.

WSE @ downstream of the railroad bridge = 167.5

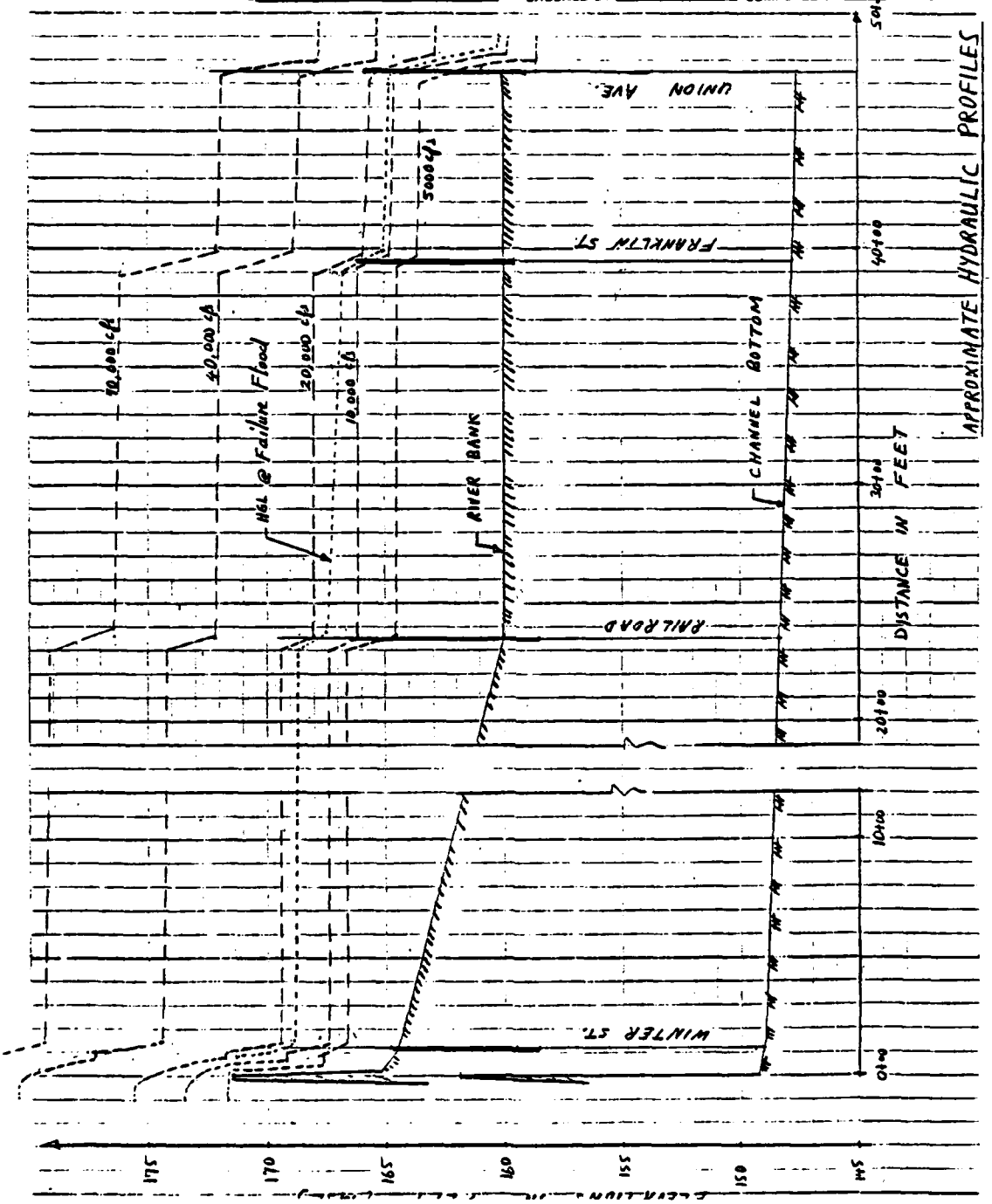
Some flood water would flow into Farm Pond. However, this was ignored in the computations because of capacity restriction at Eames Brook which connects Farm Pond to the downstream channel. As can be seen from the hydraulic profile, Page D-9, the channel bank upstream of the railroad bridge would be overtopped by about 8.7 feet.

CAMP DRESSER & McKEE INC.

CLIENT H&A
PROJECT COE DAM INSPECTION
DETAIL RESERVOIR NO. 1

JOB NO 561-2-Rt-6
DATE CHECKED 5/9/79
CHECKED BY RHS

PAGE 8
DATE 5/7/79
COMPUTED BY AWL



Reach 2 . . . Between the Railroad Bridge & Franklin St.

$Q_{P_1} = 16,100$ cfs

$A_1 = 8,800$ □' $A_2 = 19,570$ □' $L = 1,600$ ft.

$V_1 = 520$ ac-ft.

Q_{P_2} (trial) $= 16,100 \left(1 - \frac{520}{3000 - 348}\right) = 12,900$ cfs

$A_1 = 8,540$ □' $A_2 = 19,060$ □' $V_2 = 507$ ac-ft.

$V_{av} = 514$ ac-ft.

$Q_{P_2} = 16,100 \left(1 - \frac{514}{2652}\right) = 12,980$ cfs.

WSE upstream of the Franklin st. . . : 166.7

WSE downstream of the " " : 165.0

The channel bank upstream of the Franklin street would be overtopped by about 6.8 feet.

Reach 3 . Between Franklin st. & Union Ave.

$Q_{P_1} = 12,980$ cfs

$A_1 = 19,060$ □' $A_2 = 7,360$ □' $L = 800$ Ft.

$V_1 = 243$ ac-ft.

Q_{P_2} (trial) $= 12,980 \left(1 - \frac{243}{2652 - 514}\right) = 11,500$ cfs.

$V_2 = 236$ ac-ft. $V_{av} = 240$ ac-ft.

$Q_{P_2} = 12,980 \left(1 - \frac{240}{2138}\right) = 11,530$ cfs.

WSE upstream of Union Ave . . . : 164.8

WSE downstream of Union Ave . . : 161.2

The channel bank upstream of the Union Avenue would be overtopped by about 4.8 feet.

Based on the failure flood hydraulic profile the following areas are expected to be flooded along the portion of the downstream channel which was studied :

	Right Bank		Left Bank	
Location	Upstream	Downstream	Upstream	Downstream
Union Ave Bridge :	2 Office Bldgs & factory Parking lot	Bowditch Field school athletic facilities	A parking lot & sandwich outlet	Oldsmobile Dealer
Franklin St. Bridge :	-	A factory Bldg.	Residential	-
Railroad Bridge :	-	-	Commercial Bldgs :	Parking lot of a High Sch
Winter St. :	Storage for MDC	MDC bldgs :	Residential	Residential & Baseball field.

Conclusion In the event of a dam failure potential for loss of lives exists and excessive damages to residential institutional, industrial, and commercial properties are expected to occur; therefore the hazard classification for this dam is considered "high".

Note For the dam safety investigation, it is assumed that a failure would occur only at the dam which is under study and the other upstream and downstream facilities, such as dams and bridges, would remain intact; for example, we have not considered the effects on the dam under study which could be caused by failure of an upstream dam, especially a larger upstream dam.

APPENDIX E - INFORMATION AS CONTAINED IN THE NATIONAL INVENTORY OF DAMS

INVENTORY OF DAMS IN THE UNITED STATES

(1) STATE	(2) IDENTITY NUMBER	(3) DIVISION	(4) STATE	(5) COUNTY	(6) CONGR DIST.	(7) STATE	(8) COUNTY	(9) CONGR DIST.	(10) NAME	(11) LATITUDE (NORTH)	(12) LONGITUDE (WEST)	(13) REPORT DATE DAY | MO | YR
MA	337	NED	MA	017	04				RESERVOIR NUMBER ONE DAM	4217.5	7126.6	22MAY79

(14) POPULAR NAME	(15) NAME OF IMPOUNDMENT
WINTER STREET DAM	RESERVOIR NUMBER ONE (SUDBURY RIVER)

(16) REGION	(17) BASIN	(18) RIVER OR STREAM	(19) NEAREST DOWNSTREAM CITY–TOWN–VILLAGE	(20) DIST FROM DAM (MI.)	(21) POPULATION
01	05	SUDBURY RIVER	FRAMINGHAM	0	65564

(22) TYPE OF DAM	(23) YEAR COMPLETED	(24) PURPOSES	(25) STRUCTURAL HEIGHT (FT.)	(26) HYDRAULIC HEIGHT (FT.)	(27) IMPOUNDING CAPACITIES MAXIMUM (ACRE–FT.)	(27) NORMAL (ACRE–FT.)	DIST	OWN	FED R	PRV/FED	SCS A	VER/DATE
EARTH	1878	CS	40	22	3075	600	NED	N	N	N	N	22MAY79

(28) REMARKS

(29) D/S HAS	(30) SPILLWAY CREST LENGTH	(31) TYPE	(32) WIDTH (FT.)	(33) MAXIMUM DISCHARGE (FT.)	(34) VOLUME OF DAM (CY)	(35) POWER CAPACITY INSTALLED (MW)	(36) PROPOSED (MW)	(37) NAVIGATION LOCKS NO	(38) LENGTH (FT.)	(39) WIDTH (FT.)	(40) LENGTH (FT.)	(41) WIDTH (FT.)	(42) LENGTH (FT.)	(43) WIDTH (FT.)	(44) LENGTH (FT.)	(45) WIDTH (FT.)
1	800	U	168	4600	50000											

(46) OWNER	(47) ENGINEERING BY	(48) CONSTRUCTION BY
METROPOLITAN DIST COMMIS		

(49) REGULATORY AGENCY DESIGN	CONSTRUCTION	OPERATION	MAINTENANCE
NONE	NONE	NONE	MA DPW

(50) INSPECTION BY	(51) INSPECTION DATE DAY | MO | YR	(52) AUTHORITY FOR INSPECTION
HALEY & ALDRICH, INC.	29MAR79	PUBLIC LAW 92-367 8AUG1972

(53) REMARKS

END

FILMED

7-85

DTIC